THE RUDIMENTS OF
PHYSICAL GEOGRAPHY

FOR THE USE OF INDIAN SCHOOLS.

TOGETHER WITH A

SKETCH OF THE PHYSICAL STRUCTURE AND CLIMATE OF INDIA,

AND A

GLOSSARY OF THE TECHNICAL TERMS EMPLOYED.

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PREFATORY NOTE.

THE motive which has led to the preparation of this little work is expressed in the following resolution of the Senior Board of Examiners in Acts of the Calcutta University for the year 1872-73 :—"That in the opinion of this Meeting it is very desirable that elementary text-books, treating of the Natural Sciences, be prepared specially for teaching these subjects to Indian students. The text-books now available, though excellent of their kind, having been prepared for English boys, deal more especially with objects familiar or common in Europe, and have but few references to such as are interesting and familiar to the Indian learner. This want is more especially felt in teaching such subjects as Zoology, Geology, and Physical Geography. . . . . The Meeting is of opinion that the extension of Physical Science teaching in India would be greatly facilitated with [the aid of works specially adapted for local teaching]." The concluding chapters give, I believe, the only popular description that has yet appeared of the geology and climate of India. In the preparation of the former, I am indebted to Messrs. H. B. Medlicott and R. B. Foote, of the Geological Survey, for valuable corrections up to date.

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INTRODUCTION.

WHAT PHYSICAL GEOGRAPHY IS ABOUT, AND HOW TO LEARN IT.

Before we enter systematically on the study of Physical Geography, let us try to gain a general idea of the kind of knowledge to which this name is applied. To do so we will take a scene that must be familiar to most of those whom I address. After some rainy morning in July or August, I will suppose you to take your stand on the bank of the river that flows by your village, and, perhaps, in mere listlessness, watch the turbid flood swirling past. The chur opposite, which the river left dry when its waters fell at the close of the last rainy season, and which till lately was covered by a rich green crop of Indigo or bright yellow mustard, is now more than half cut away and buried beneath the waters; and the steep bank which the stream has cut along the part not yet submerged, is rapidly giving way, and masses, many times larger than the house you live in, from time to time detach themselves, and falling, are swallowed up by the deep muddy stream. Has it ever occurred to you to ask yourself *why* these things are as you see them? You have probably witnessed the same kind of thing scores of times, and you may perhaps think that there is nothing very interesting in this swelling and shrinking of the river, in its heaping up churs and again destroying them, in the waters hurrying on always in one direction and never returning on their course. You know that the same thing is repeated year after year, and expect that if you live fifty years and come back to the spot you now stand on, the scene before you will be just the same as that which you gaze on to-day. But now consider a little. On thinking the matter over, you may recall to mind that the chur that is now so rapidly disappearing before your eyes was not in exactly the same place; nor was it so large as that which, in a certain [illegible] it replaced, and which you remember two [illegible] ago. Moreover, that the stream, which, during the [illegible] months, separated it from the bank you stand on [illegible] during this last season, deeper than that which [illegible] between them in the cold weather of the year [illegible] and if you ask the old people of the village, they will, perhaps, tell you that, thirty or forty years ago, the river itself was a moderate sized khall, and that the old river channel, seven or eight miles off, which is now little more than a string of pools, was at that time a well-filled river, which could scarce be crossed without a boat even in the dry weather. Such things happen constantly in Bengal. Perhaps this may have aroused your curiosity, and you begin to enquire of people who have come from other parts of the country, whether they have known such changes elsewhere. Among others, you question some one who for many years lived in the Maimansing, Dhaka or Bograh District, and you learn from him that it is well known to the people of those districts, that, about sixty or seventy years ago, the Brahmaputra, which up to that time had flowed past Maimansing and a long way to the east of Dhaka and of the high Madhapur jungle to the north of it, changed its course, and has ever since flowed to the west of the Madhapur jungle, and a long way west of Dhaka, joining the Ganges at Goalundo, where the railway now terminates. Some one else—it may be from Rangpùr—tells you that, at a somewhat earlier date, the Tista, a large river from the Himalaya, which used to flow southwards into the Ganges at Jaffirganj, in 1787 suddenly changed its course and opened out a new channel to the eastward, in which it has since flowed, joining the Brahmaputra above Dewanganj.

These are not mere vague traditions; they are well established historical events. Old maps exist, which were drawn before these changes took place, and they show that these rivers then flowed as I have told you. So you see that the changes which you may have noticed yourself in the stream at your feet, or which have been witnessed by persons whom you see daily, are but small examples of much greater permanent changes which a little enquiry will enable you to learn about. But we have a great deal more to learn from the river before you. You can see that the water is very muddy; before it is fit to drink, you must let it stand for some time. Fill a clean pot with this muddy water, and let it stand undisturbed. In the course of a few hours, you will find a layer of earthy matter at the bottom of the pot, very much like the loam of the fields around; but the water must stand for several days before it is quite clear, and then you will find a thin layer of very fine mud or clay that has settled down on the top of the coarser sediment.* This it is, that was mixed with the water and made it so thick and turbid; and you can see that the water of the whole river is just as muddy as that with which you filled your pot. Your own experiment has shown you that the water must stand quite still to become clear, and that even then it takes a long time to do so. But the water of the river is all in motion, and being unable to deposit its mud, carries it down with it to the sea. What becomes of it there we shall learn afterwards, but in the meantime it may occur to you to ask where it all comes from, and what must happen if the same thing goes on year after year, as you know it does. The first question is soon answered. Turn to the little streamlet or drain a few yards off, that is still running rapidly, carrying away the rain water that has fallen in the morning, and which is a great deal dirtier than that of the river. You know that when the rain fell, the water was pure and clean, for perhaps you may have had your clothes wetted by it, but it only wetted, and did not dirty them. Clearly then the mud and dirt with which the water of that little drain is so highly charged has been carried away from the land; and the same thing is true of the swollen river. All that great body of water was rain a few hours, days, or weeks ago, and having fallen on the ground, has gradually collected in little channels and drains like that beside you, and as these joined together, they formed at first small streams, then larger streams, and lastly a river. All the mud and dirt that it contains has been washed off the land, and is being carried down to the sea, and there are no rivers running back from the sea to bring it back to the land. Is the land then always being washed away into the sea? Yes, at all times. Every river is doing its work of destruction; but it is not all destruction. You may learn from the cultivators about you, that some neighbouring jhíl is being gradually filled up by the earth settling down from the water that overflows into it from the river at each flood; and year by year some little piece of it that was formerly too deep under water to be cultivated, is reclaimed and added to the rice lands around its margin. We shall see presently that the whole of the broad rice-fields of lower Bengal have been actually formed in this way. It is a very slow process. It must have taken many thousands of years for all Bengal to be formed by the mud settling from the rivers; but we shall find presently that the ground contains the evidence of its own history, a history which we may read by simply continuing to observe, and to reason on what we observe, in the way that I have now shown you; and thus we learn that all the great plains of Bengal must at one time have been occupied by the sea, and that this sea has been gradually filled up by the sand and mud brought down by the rivers.

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* This is what is called an *experiment*, and what I suppose you to have been watching is an *observation*. It is by these two methods that all our knowledge of nature has been gained.

We will now leave for a time this story of the making and destruction of land by the river, and will turn our attention to the water. What makes the river flow always one way, and why is it so full at a particular season of the year, and low at other times? We shall find the answers to these questions not less interesting as that which we have already arrived at. In the first place, a very little observation will show you that water will not run up-hill. If a cultivator wants to water his crops from some neighbouring pool or well, he must make a channel that is a little higher at the end where the water is poured into it than where it delivers it on his field; and by means of a paicottah, or a scoop, he must raise the water from the pool, and pour it into the higher end of the channel. The more his channel slopes, the faster does the water run down it. Now what is true of his little water-channel is equally true of the river. To your eye the surface of the river appears level, but that is only because it slopes so little, that your eye cannot distinguish the slope from the real level of a jhil. If you go down the Húghli in a boat from Barhampúr, or Múrshidabad, to Sagar Point, at every part of your journey the water-surface will seem to be as level as that of the river before you; but we know from measurements very carefully made by surveyors, that in this journey you have really gone down a slope, such, that at the end of it, you would be about 60 feet lower than when you started. In like manner if you were to start in a boat from Banares to travel to Dacca, the water would seem to be quite level from first to last; but actual measurement shows that you would have descended about 240 feet; and had you ended your journey at Mungher, you would then have descended more than 100 feet without being in the least aware of it.

The river flows then always in the same direction because it flows down a slope, but the slope is so gentle that it is necessary to use a very delicate instrument termed a *level* in order to measure the fall. The force that makes the water flow is the same that makes a stone fall back to the ground when you throw it into the air, and is called *gravitation.* We shall have much to say of this force presently.

If you have clearly understood what I have said so far, your own reason will tell you that the water must be raised by some means or other to the place where the river begins. To explain how this is accomplished, we will have recourse to another very simple experiment. Take a shallow dish which must be such that water cannot soak into it. Fill it with water and let it stand in the open air, where it will not be disturbed. If the weather is fine it will slowly disappear; and in the course of a day or two it will be all gone, and the dish will be dry. It has all gone into the air; you cannot see it because it has become a part of the air, and has assumed the state which is termed *vapour.* The air always contains some of this vapour, which it gathers from the surface of the sea, the rivers, and indeed wherever there is water. Most of it comes from the sea, which is always *evaporating* or giving off vapour under the heat of the sun; and this vapour is carried by the winds to places, a long way from where it was produced. Much of it is carried to the land,

and sometimes, as between June and September, when the wind blows steadily and strongly from the sea, it is carried far into the interior. But it does not always remain vapour. You may often observe, a few hours after sunrise, when the sky has been quite clear from cloud during the morning, that clouds with rounded tops and flat below gradually make their appearance, not visibly coming from anywhere, but forming high up in the air. Now these clouds are the vapour of the air again converted into water, and although they sometimes disappear again by re-evaporating as the day wears on, at other times they get gradually thicker and darker, and at last send down a shower of rain. It is then from the vapour which is carried in the air that rain is formed, and we have already seen that it is the rain water that collects to form rivers.

Let us now stop for a moment, and recapitulate what we have learned. The sea furnishes vapour to the air, just as, on the small scale, a dish of water will do if left standing. The vapour is carried away by the winds, which are air in motion, and being reconverted into water in very minute drops forms clouds; the clouds, when very thick, furnish the rain, which is merely those very minute drops uniting together to form larger drops; the rain runs off the land, carrying with it particles of mud and sand, and then collects in streams and rivers, which are turbid with the materials brought into them by the drainage water. These flow down the sloping surface of their beds into the sea, constantly carrying thither portions of the solid land, which are never brought back with the evaporated water. At the same time when rivers overflow their banks, and fill jhils and places where the water is still, some of this earth settles down and forms new land; but, after all, this is very little in comparison with that which is carried away. The rest sinks gradually to the bottom of the sea, and if there were no new land formed, by some power which we have not yet spoken of, in the course of time all the land would be carried away; first the mountains and hills, which are wasted more rapidly than the plains, and finally the plains themselves. But there is such a power, as we shall find out somewhat later on, though its action is not so readily to be observed as the familiar changes produced by the rain and the rivers; and it will be better to defer its consideration until we have made some further progress in our knowledge of more familiar things.

You will now be prepared to give a partial answer to the question. Why is the river so full during a part of the year, and so low at other times? You know that its fulness depends on the quantity of rain that falls, and that rain falls much more abundantly from June to September than during the remainder of the year. But this answer only suggests other questions. For we have to ask the very similar question, why does the rain fall more abundantly at one season than another? and if we further reply, because the wind then blows from the sea, which furnishes abundance of vapour, while during the dry cold weather it blows from the land where there is very little water to furnish vapour, both of them facts that a little observation will show us to be true, the change of the winds still remains for explanation. This too may be explained as we shall see, but not in a few words, nor without a great deal more observation than we have yet given to what is going on around us.

Now observe what a number of interesting enquiries have been suggested by a few observations, thoughtfully made, on things so familiar to you, that perhaps you have never yet thought there is anything to be learned from them. They have led us on to the strange and unexpected conclusion that the very land on which we live is gradually wasting away, and since there is so much land still left to live on, it seems probable that there must be some means by which new land is formed; but what those means are we have not yet learned. We have learned, too, that even the variable winds show some regularity, since they blow from one quarter during a part of the year, and from another quarter at another season, but we have yet to learn what is the cause of this regular change; and we have also to learn how clouds are formed from invisible vapour.

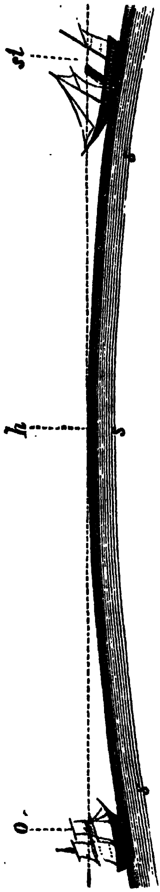
But the most important lesson that you will have gained, if you have, as I suppose, really seen and thought over what I have described, and have not been idly contented with reading what I have written, will be this; That the best of all kinds of knowledge is to be gained, not from what is written in books, but by watching what takes place around you, thinking over what you see, and whenever you can, resorting to experiment, to decide something or other which observation alone has not sufficed to explain. All the knowledge we have of nature has been gained by these two methods, *observation* and *experiment;* and the chief use of books is to tell you of what you cannot see for yourself, but which others have seen, and to show you how others have thought and enquired about these things, so that you may follow their example.

You will now have gained some idea of what is meant by Physical Geography. It is the story of the changes that go on, and are always going on around us in this world of ours. It teaches us, as far as such things can be explained, *why* the world is as we see it. Not indeed why it *exists,* any more than it teaches us why we ourselves exist. Such questions cannot be answered by any science. But it will teach us that every change that we see in progress goes on regularly, however irregular it may seem at first sight, and that everything is subject to change. Moreover that nothing takes place without *a cause.* When we have found out an explanation, and found that it is always true, such as that which we arrived at a short time ago, *viz.,* that rivers are fed by rain, and always flow down a slope towards the sea, or that land is wasting away and is somehow renewed, we call it a natural law, and the object of Physical Geography is to find out what are the laws according to which changes take place around us.

CHAPTER I.

THE EARTH AS A PLANET.

THOSE of my readers who live in Máldah, Púrnia, or the northern part of Bhágalpúr, on looking to the north some fine October morning, may have noticed along the *horizon* (that is, where the land seems to end and the sky to begin), a line of bright white mountain tops glistening in the morning sun. They are the snow-covered crests of the Himálaya. Viewed from so great a distance, it is hard to believe that they are of the great height that we know them to have; for the snow does not lie much below 16,000 feet, or at a height of nearly three miles above the level of the rice-fields from which I suppose them to be seen. But a great part of the lower slopes of the mountains are hidden by the seemingly level plain on which the observer stands. This may seem strange; but it is only an example of a very familiar kind of appearance, from which we learn that the earth we live upon is really not flat, but a globe or ball; but which is so large, that so much of it as we can see at any one time seems to be flat. The surface of the sea, when calm, is much smoother and apparently flatter than the rice-fields of Bengal; and here it may be seen almost daily, that distant objects, ships for instance, are partly hidden by its really curved surface. When the man on the look-out, at the mast head of a vessel, first descries a distant steamer, he probably sees nothing but the smoke. Presently, as it draws nearer, the tops of the masts seem to emerge from the water on the horizon. Then they rise higher and the funnel appears, and lastly the hull of the steamer comes into sight. It does not matter from what direction the steamer comes,—north, south, east, or west,—the several parts of the steamer come into sight successively in the order I have mentioned, the highest parts first, the lower last. Now if the earth were really flat, this would not be the case. The steamer



would at first seem a mere speck in the far distance, and as soon as its parts could be made out distinctly, the hull would be seen as well as the masts and funnel. The annexed diagram will help to make clear the above description of what is actually seen, and how from it we learn that the world is round. *o* is the observer at the mast head, *s* the sea, *h* the horizon that bounds the visible part of the sea-surface, and *st* the distant steamer. I must however observe that in comparison with the curvature of the earth, the size of these vessels is greatly exaggerated in the figure; in reality, if only the tops of the steamer's masts were seen by the observer at *o*, the two vessels must be many miles apart.

The moon is a globe like the earth, but not so large. With a telescope we can see that she has the appearance of a ball. We are all familiar with the changes in her appearance, which are called her *phases;* how from a narrow crescent of light she grows to a semicircle and thence to a full round. If we take a ball of white clay and hold it before a single lamp, so that only one side is illuminated, then, looking at it successively from every side, it will present a series of appearances very like those of the moon. If we could stand on the moon and look at the earth, our earth would look very much like the moon as we see it, (except that it would appear much larger) and would go through a similar series of changes, because both the moon and the earth are illuminated in the same way by the sun. But sometimes when the moon is full, the earth passes between her and the sun, throwing a shadow on her illuminated surface, just as a second ball will do if interposed between the lamp and the white ball that it illuminates. Now this shadow is always round, such a shadow as a ball casts on a white wall; it is *round*, whichever face of the earth is turned towards the moon, and since a ball is the only form of body that *always* throws a round shadow and no other, this again assures us that the earth is a ball.

I might easily multiply proofs of the roundness of the earth were it necessary, but since one complete proof, such as the shape of its shadow, is really all that we need, perhaps it will be more useful if we now consider the matter and see if there are no difficulties to be met. One difficulty will perhaps occur to some of my readers. If the earth be a ball, it will be readily understood that those who live on the top should remain standing, but it will be asked, 'do people live on the other side of it, and if so why do they not fall off?' Now it is unquestionable that people *do* live on the other side of the earth, *viz.*, those who live in Peru and Chili in South America, for when it is about midnight with us and everything is dark and quiet, it is a little after noonday with them, and the sun is shining brightly over their heads. So too, when a telegraphic message is sent to America, which, with a little preparation beforehand, may be done so quickly that it reaches America almost at the same instant of time that it leaves Calcutta; if it is sunset when the signalling clerk in Calcutta is sending the message, it is sunrise in America to the clerk there who is receiving it. Again, ships often sail right round the world, going always to the east, and yet returning to the port from which they set out. Yet those who live in America, and the sailors in a ship sailing round the world, see the earth or water at their feet, and the sky above them, just as we do, and they stand as firmly; and if one of them throws a ball into the air, it falls back again to the ground just as it does here. This is perhaps, at first, not very easy to understand; but we may understand it, if we only think what we really judge by, when we speak of throwing a ball *up* and of its falling *down*. We really refer *up* and *down* to the position of our own bodies as we stand; and we call the direction in which our heads point, *upwards*, and that in which our feet point, *downwards*. And since Americans stand just as we do, that which they call *up* is almost* identically the same direction in space that we call *down*. Consequently when a ball is thrown up into the air in America, it moves away from the earth, in almost the same direction as another which is falling towards the earth in Bengal. With a large ball before him to represent the earth, such as a *Kadú*, or a common round earthen pot with the neck knocked off and filled with clay, rounded off at the top, if a terrestrial globe be not at hand, to represent the earth, my readers may, with a little thought, realize these facts to their mind. And when they have clearly realized them, they will have gained an important step in knowledge, *viz.*, that all we know about *upwards* and *downwards* is the direction judged of by our own position in standing.

This much being clearly understood, we have yet to explain why a ball always falls to the earth, and why we stand firmly on it, when our heads point in one direction and those of the Americans in a direction almost exactly opposite. This is because the earth, or globe, on which we live, attracts or draws everything towards it. And not only does the earth do this, but everything that we can see and handle, everything that has *weight*, does exactly the same. The ball that falls to the earth attracts the earth towards it in the same *way* that it itself is attracted by the earth, but the strength of the pull exerted by each is in proportion to its size and its intrinsic heaviness, since a ball of lead exercises a stronger pull than a ball of cotton of the same size. Now the earth is enormously large, the ball very small indeed; and therefore to our senses, the ball seems to be the *only* body pulled, and the only body that seems to move. We stand firmly on the earth because it pulls us, and quite unconsciously our bodies pull it; and when we jump up we exert ourselves against this mutual pull, which soon brings us back to the surface. What we call the *weight* of a body, such as a log of wood, is really the pull of the earth and the log towards each other, which pull we feel when we try to raise it and find it to be heavy. This is felt everywhere on the surface of the earth, and is very nearly the same (but not exactly the same) on every part of it.* The power of pulling, which is exerted by everything that has weight, is called *gravitation*.

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* I say *almost*, for the part of the earth directly opposite to Bengal, and called its *antipodes*, is in the Pacific Ocean and not in America.

And it is not only things on the surface of the earth that thus gravitate or are drawn towards it. The moon, although at so great a distance that it looks like a moderate sized ball, whereas it is in reality 2153 miles across, or $\frac{11}{49}$ the size of our earth, is attracted by the earth, and attracts it while it moves round it. Indeed it is because it is pulled towards the earth, that it remains always at nearly the same distance, and does not fly away from it into distant space. A simple experiment that every one can try for himself will help to make this clear. Take a stone or a lump of clay, tie it up in a piece of cloth, and fasten it to the end of a string two or three yards long; then, holding the other end of the string, stand in a clear space and whirl the stone rapidly round you, turning round yourself at the time. You will then feel that the string is pulled by the moving stone, and if it is thin and weak it will break, and the stone will fly off. So the moon would fly off from the earth if it were not pulled towards it. There is, it is true, no visible link or bond between the two, like the string in our experiment, but neither is there any visible connection between the earth and a ball that is falling towards it, and yet evidently they attract each other. In the same way, the sun, which is much further off from us than the moon, and nearly one and a quarter millions of times larger than the earth, attracts both the earth and the moon; and with such force, that if they were not both in rapid motion round the sun, they would fall into it and be first melted, and then in great part turned into vapour by his heat, which far exceeds that of the hottest fire we can make. And this leads us to say something about the sun, that glorious luminary, whose warmth and light are so grateful to all living things, and without which indeed no living thing on the earth's surface could continue to live for the space of two days, so needful are they to life itself.

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* In India it is a little less than in England, and in England less than in Greenland; while on the top of the Himálaya it is less than on the plains of Bengal.

What is the sun? A few years ago we should have been unable to answer this question nearly so well as we can now. Its distance is so immense that if we could leave the earth and travel towards it, at the rate of a railway train at full speed, say thirty miles in an hour, it would take us 338 years to reach it; it is so large that if we were on its surface and were to travel round it at the same rate of speed, we should be more than nine years completing the journey; whereas, if we were to make a similar journey round our earth, we should come back to our starting point in about one month. And as to its heat, we all know that if we make a good sized bonfire, and stand ten or twelve yards off, we no longer feel the warmth given out by the flame; whereas, notwithstanding his enormous distance, the heat of the sun is sometimes so powerful that we can hardly bear it. By a method which was discovered only a few years ago, the light of the sun has been made to reveal to us that that luminary consists of materials for the most part like those of our earth. Iron, for instance, is one of them, but it is not solid nor even melted iron, at all events on the outside of the sun, but is rather vapour, that is, it is in much the same condition as the air we breathe, and it is kept in this condition owing to the intensity of the heat. Besides iron, there are many other substances, some of them metals, and all like it in a state of vapour. There are liquid matters beneath these, but we cannot tell very well what they are. We have already seen in the introductory chapter, that the heat that reaches us from the sun, evaporates water from the surface of the sea. We shall see afterwards that the winds which bring us rain are set in motion entirely by the sun's heat. Plants will not grow unless they receive both heat and light, and we ourselves should be able to do very little without the light of the day, and we should soon perish of cold if deprived of the sun's genial rays.

We must now turn our attention to one very important variation in the effect of the sun upon our earth, *viz.*, the alternation of day and night.

When we see the sun rise in the morning, and after ascending till almost over our heads, descend and set in the west, our first impression is that the sun really moves past us, and that we ourselves are at rest. But we have learned in our discussion of the shape of our earth to be cautious in trusting to first impressions, and that to arrive at the truth, we must test our first conclusions by further observation, and then compare together our several observations and impressions correcting one by the other. The present is a case in which it becomes necessary to do so. The question which we have here to ask ourselves is this:—can we ourselves be in motion without being sensible of it? and, secondly, if this be so, and if we are moving past an object really stationary, will the appearance be the same as if the object were moving, and we ourselves at rest? A little experience will show that both these questions must be answered in the affirmative. If a person in a boat at anchor in the middle of a very wide river sees another boat drifting past him with the current, and if he does not actually know from previous observation that his own boat is anchored, he is unable to say whether his own or the other boat is in motion. All he can be sure of is, that one is moving past the other, but he cannot tell without looking at the rope which he knows to be attached to the anchor, whether his own boat is stationary and the other moving, or the former moving and the latter stationary, or finally whether both are not moving in opposite directions. So again, in a railway station at which two trains are standing, the observer being in one of them. If the other train begins to move off gently, it is impossible to tell by merely looking at the passing carriages, whether they or the observer's own carriage is moving; until he either feels the rattling motion of the carriage, or looks at the station shed which he knows to be at rest. But the earth does not shake or rattle in moving, and the only mode of judging whether the sun or the earth is the moving body is to look at the stars. And they, too, will tell us nothing, unless we know or believe that like the station shed of the railway they do not move. What we then see is, that if it is the sun that moves, the stars must move too, and at nearly the same rate, for all seem to go round in the same way; and therefore we can only conclude that either the earth is turning round from west to east, and presenting every side in succession to the sun and to each particular star, or else that the earth is stationary, and all the heavens moving round it from east to west. So we have only arrived at this result; that we require a great deal more observation to decide the question. This astronomers have made for us with great care, and the result is, that it is proved that the earth turns round like a spinning top, and the sun, *relatively to us*, is almost stationary.* Every side of the earth is in turn presented to the sun and is illuminated by it, producing day, while it is night on that side which is turned away from the sun. The ball of white clay that we used a short time ago to illustrate the appearance of the moon may now be used to represent our earth. Thrust a wire or thin stick through the middle of it, make an ink mark on the ball a little above the middle to represent India, and then holding the stick a little inclined, turn it round slowly before the lamp. The marked spot will be lighted up while it passes in front of the lamp, representing day, and will be in darkness, while passing on the opposite side, representing night.

The earth revolves once in 24 hours, or in one day and one night, around a line that passes through its centre. This line is termed its *axis*. In the clay ball or in a model globe, the axis is represented by the wire or stick thrust through it, and the two points at which it protrudes from the ball are called the *poles*. But in our earth this axis is merely an imaginary line, the ends of which are called the earth's poles; in free space, the earth requires no support; for there is nothing but gravitation, and the motion it already has, to make it go one way rather than another; and these conjointly make it travel round the sun, in much the same way as the moon travels round the earth.

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* There is a little instrument called a Gyroscope, resembling a boy's top, by which it may be proved to the eye, that the earth moves, and not the sun or the stars. It is made to spin very rapidly on a kind of moveable support, and it is a known property of this instrument that the axis of the spinning top keeps pointing in the same direction, however the support may be moved. Now, if it be set spinning pointing to a particular star, it will remain pointing to that star, although the star may seem to have moved some distance across the sky. The star then has not moved, but the earth has.

The earth travels round the sun once in a year, while the moon travels round the earth once in a lunar month. If either of them left a train of light behind it to show where it had passed, and some one could see this from one of the stars, it would look like a ring; that of the earth being very much larger than that of the moon. The sun would be seen in the middle of the ring traced by the earth, and the earth would be in the middle of that traced by the moon. Moreover, the moon and its ring would be seen to move round the sun together with the earth, the moon being always at *nearly* but *not quite* the same distance from the earth, and the earth at nearly but not quite the same distance from the sun. Other balls like our earth, one of them thirteen hundred times larger, and having four moons, and another with a peculiar ring around it, and accompanied by eight moons, would be seen at different distances from the sun, all moving round it in the same direction as the earth. As we see them from the earth, these bodies look like stars, except that they move among the real stars; but they are very different from the stars and are called *planets*. The brightest of them all can be seen at one time of year in the west for a short time after the sun has set, at another time of year in the east for a short time before the sun rises, and it is therefore sometimes called the evening star, and at other times the morning star. Astronomers call this planet Venus.

The sun with the earth and other planets and their moons, and a vast number of smaller bodies of like character, all of which circle round the same central body, is called the *solar system;* and if viewed, as I supposed just now, from some star, the whole would be seen hurrying through space, with the enormous speed of four miles in each second of time, or more than three hundred thousand miles in a day. But the real stars are so far off, that if we could watch this motion for many years, the sun and its planets would seem scarcely nearer to them than they are now.

My readers will now understand how small and insignificant a body our earth really is, when we think of it in comparison with the sun and the stars. The real stars are all suns like our own, and some of them very much larger; but at so great a distance, that they look only like bright points; and indeed by far the greater part of them cannot be seen at all without the help of a telescope.

Let us now sum up what we have learned. Our earth is a globe or ball that turns round or revolves on its own axis, (which is only an imaginary line passing through its centre), while it travels round the sun. It turns completely round its axis once a day; and as it revolves, that half which is turned towards the sun is lighted up by it, and has daylight, while the side that is turned away from it is dark, and has night. The earth also travels round the sun once in a year, and the moon travels round the earth in the same way once in a month, while she revolves on her own axis also once a month. The same face of the moon is therefore always presented to the earth, whereas all sides are successively presented to the sun. That side of the moon which is turned towards the sun is bright, and that which is away from it is dark; so that if people could live on the moon, they would have day and night as we have, but their day would last nearly half a month, and their night another half month. There are other bodies called planets that travel round the sun like our earth, and some of them have several moons accompanying them. Were we writing about astronomy, we should have a great deal to say about these planets, but we must return to earth in the next chapter, and we shall find that there is plenty to interest us on our own earth, although it is so small in comparison with the sun and the stars. Lastly we have learned that this system of sun and planets is travelling rapidly through infinite space, and that although at great distances from each other, they are kept together by that mutual attraction, or pulling at each other which is called gravitation, and which is the same cause that keeps us standing on the earth, and causes a ball that has been thrown up into the air to fall back to the ground.

CHAPTER II.

THE ATMOSPHERE.

OUR globe is completely surrounded by a covering of air, which is called its *atmosphere.* That air is *something*, although we cannot see it, we must acknowledge, when we call to mind that we feel its pressure with every puff of wind. And when the wind is very violent, as in those great storms that pass over Bengal sometimes at the change of the monsoons, we see the effects of its power in uprooted trees, wrecked boats, houses levelled and scattered, and sometimes, most terrible of all, in destructive floods of sea-water, which the wind first piles up on the sea and then drives forward over the land, destroying and submerging everything in their path. Clearly then air is something, and at times a very powerful something.

Although air is met with everywhere on the surface of the earth, even on the tops of the highest mountains, we have no reason to believe that it extends very far from the earth; or that, for example, it fills all the space between us and the moon. Even on the lofty ridges of the Himálaya, the air is, so to speak, of thinner consistency than here on the plains; that is to say, every cubic foot of it contains a less weight of air than down here in Bengal: and one reason why it is so difficult to climb very high mountains, and that no one has ever yet reached the top of the most lofty mountains, is that the air there is so attenuated that people cannot breathe well, and soon become exhausted. We do not know exactly how high we should have to mount from the earth, to be beyond the atmosphere altogether, but at a height of 50 miles or about ten times as high as the highest peak of the Himálaya, there must be so little, that if it were to blow with the speed of one of our great storms, we should not feel it. The atmosphere is, then, a very thin layer compared with the size of the earth. If we suppose our earth to be represented by a ball one foot across, two sheets of ordinary country paper laid on the surface, one over the other, would about represent the thickness of the atmosphere.

To understand what the air does, we must first know what it consists of. It is a mixture of gases, chiefly two, which are called by chemists *oxygen* and *nitrogen*. Neither of them can be seen, because they have no colour; nor have they any smell or taste; but as I have already mentioned, we can feel them when they move in a wind, and by proper means we can separate and weigh them. These two gases are called *permanent* gases, because no one has ever been able to convert them into a liquid like water, still less into a solid like ice or stone. But besides these, air always contains the vapour of water, that is to say water in an invisible gas-like condition; but unlike oxygen and nitrogen in this; that if cooled down sufficiently, it is reconverted into common liquid water. Water in this gaseous state is commonly spoken of as water-vapour or simply *vapour*. In the introduction we spoke of the evaporation of water which takes place when a dish of it is exposed to the air. A wet cloth, for instance, if hung up in a wind, is soon dried; because the water that soaks it escapes from it in the form of vapour; and if the sun is shining upon it, or if it be hung near a fire, it dries all the faster, showing us that it is heat or warmth that changes water into vapour, while another experiment will show us that cold brings back the vapour to the state of water, and sometimes even into the solid state of snow or ice. Procure a large piece of ice; crush it, and fill a brass or tin-pot with the fragments, nearly up to the top, taking care that none of it rests on the edge. Dry the outside thoroughly, and then let it stand for a short time in a shady place. The vessel soon becomes cold, but for a minute or less, according to the state of the air at the time, it remains dry on the outside. After a time, however, the polished surface will become dulled, and if you then draw your finger over it you will find it to be wet. The water has not come through the vessel as might be supposed at first sight, but is water which existed as invisible vapour in the air around, and which has been turned into water again or *condensed* by the coldness of the vessel. If this experiment be repeated, some salt having previously been mixed rapidly with the ice, the vessel is made much colder than before; and the vapour of the air will be condensed on the outside, not in minute liquid drops, but in fine white solid filaments, which are almost exactly the same thing as the snow that lies on the tops of the Himálaya mountains, and from which, as I dare say my readers know, they take their name Himálaya 'the abode of snow.'

We are now prepared to understand how fog, clouds, rain, snow, and hail are formed, and in part, why we often find the grass and leaves quite wet in the early morning, though no rain has fallen during the night. In all these cases the vapour of the air has been condensed by cold.

A *fog* is produced by the cooling of the air that rests directly on the ground. In the cold weather it may often be seen to form very soon after sun-set.* The vapour in the air begins to condense as it cools, and is converted into water drops so small that for a time they remain floating in the air, and cannot be seen apart from each other. But if a perfectly dry cloth be hung up in such a fog it will soon become damp. A *cloud* is much the same as a fog, but formed high up in the air, and is very variable in shape, since the substance of the cloud is continually changing. When the sun shines on one of those white isolated clouds, rounded on the top and flat below, that are so common about noon day in fine weather, the upper surface of the cloud is evaporating under the sun's rays, while more vapour rising from the earth is condensed and added at the bottom; the cloud seems to be the same, because it remains in the same place, but in reality the condensed vapour that composes it is constantly changing. Now if a cloud of this kind grows very large and thick, and unites with other clouds round about it and higher up in the atmosphere, which of course can take place only by more vapour being condensed from the air, it forms at last a rain-cloud. The very minute water drops that compose the cloud become larger, then unite with one another, and finally fall to the earth as rain drops. It seems at first hard to believe that all the water that falls in a heavy shower of rain should have existed in the air, only a short time before, as invisible vapour, but there is no doubt that it is so. One may learn much by watching the clouds for an hour or two together, and noticing their changes of form and size; just before one of those thunder storms so common in March and April, which we call *north-westers*, new layers of cloud may sometimes be seen to form so rapidly, as entirely to obscure the sky overhead in the course of half an hour. In February and March it sometimes happens that, together with the rain, lumps of ice fall. These are termed *hail-stones*, not because they are really stones, but simply because they are solid, and falling from a great height in the air, they are as destructive to trees and crops as if they were really stones. They are very large rain drops that come from some cloud high overhead, where it is so cold that they are frozen into ice. *Snow* is also a kind of frozen rain, but it is very light, and there is this difference in its mode of formation, that it is changed at once from invisible vapour into little frozen needles; just as, in the experiment with the ice and salt described a short time ago, the vapour condensed on the surface of a very cold vessel becomes at once a white frozen layer of a snow-like substance, without passing through the condition of water. We never see snow fall on the plains of India, nor even on the hills south of the Himálaya, because it is never cold enough, but on the higher peaks of the Himálaya it falls abundantly, and this it is that makes them so white. Snow is very light; as it falls, it looks much like flocks of cotton wool; and where it falls, there it remains, until it melts or is drifted into heaps by the wind. In the winter time in Europe, it sometimes accumulates in this manner till it forms a layer over the ground, several feet thick, and in severe winters houses are sometimes buried in the snow drifts. On high mountains it collects in the same way in hollows, forming beds many hundreds of feet thick; what becomes of it then we shall see later on, when we have to speak of glaciers.*

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* In villages and among houses, a great deal of smoke is generally mixed with the fog; but this is not the case when it forms over an open plain, such as the Calcutta *maidan*, or over tanks, jhíls, and marshy places, far away from houses.

* Chapter VII.

There is one other form in which the vapour of the air condenses, and which is familiar to us all. Often, after a fine clear night in the cold weather, we find the grass and trees quite wet, and large drops of water resting on the leaves. This is called *dew*. It is the vapour of the air condensed on the cold surface of the leaves. A cloth left out on the grass on such a night will become as wet as if it had been dipped into water. When it is so cold that the dew freezes as it forms, it is called *hoar frost*. This is often seen in the Upper Provinces of India, on the Nilgírí hills and even no further off than Hazáríbágh, after a very cold clear night in December or January.

We see then that fog, clouds, rain, hail, snow, dew and hoar-frost are all formed in the same way, *viz.*, by the cooling of the air, which then gives out in a liquid or solid form a part of the vapour that it contains. The vapour comes originally from the surface of seas, rivers, tanks and even the land if it is wet, and the chief cause of its evaporation is the heat of the sun. It is then owing to this genial heat, that we are indebted for those refreshing rains, that cool the air and make our trees and food crops grow.

But this is only a part of the work done by the sun's heat in our atmosphere. It is the sun that sets the air in motion, and causes those winds, by which vapour is carried from the surface of the ocean and distributed over the fields and forests in rain; by which therefore rivers are fed, and the land made habitable and covered with verdure. To understand how all this is brought about, we must go back to certain simple rudimentary facts which we may gather from every-day experience. In order to learn how the air is affected by heat, a good way is to watch what takes place round about an ordinary fire. If we make a large fire of twigs, dead leaves or straw in the open air, and if there be no wind blowing at the time, the smoke goes straight upwards; but if any burning leaves or twigs happen to lie a little on one side, the flame and smoke from them are drawn towards the rest of the burning mass, showing that currents of air are drawn in towards the fire at the bottom. This air is heated by the flame, and then rushes upwards, carrying with it the smoke, bits of ash, and similar light bodies. It rises for the same reason that a piece of bamboo, if thrown into the water, at once rises to the surface. Just as the bamboo is lighter than the water, so the hot air is lighter than the cold air around. Cold smoke is not light and does not rise, as may be seen any evening in the cold weather, when the smoke that is produced by the fires of the village hangs low down about the houses, and gradually settles to the ground. Now if a fire be very large, such as may be seen when a village is burning, a strong wind blows in from all sides towards the flames; and when a large forest is burning, (as sometimes occurs in the great forests of America;) and in the conflagrations of great cities, such as that of London in 1666, which burnt for four days, or that of Chicago in the United States a year or two ago, the wind that is produced around, blows with the force of a hurricane, rushing in towards the flames.

The heat of the sun produces effects similar to these. It is true that it does not heat the air so intensely as a great conflagration will do, but the tracts that are affected by it are much more extensive, and the winds therefore, though not so violent as around a burning city or forest, prevail over very much larger spaces. But it may be asked, since the sun is shining at the same time over half the earth, how is it that one place is so much hotter than another. The reasons are chiefly two-fold. First these places that have the sun immediately overhead are hotter than those where it does not rise so high; just as, at the same place, it is hotter at noon when the sun is highest, than in the morning and evening when it is low. And, secondly, land is much more quickly heated than water, so that on the open sea at midday and even on and near the sea shore, it is much cooler, in April and May, than in the interior of Bengal; and it is hotter still in Central India and the Panjáb, which are still further from the sea.

On the other hand, at night time, when the sun is below the horizon, and both land and water, as well as the air above them, are cooling down, giving out their heat to the starry space, the land cools faster than the sea. And in the same way, in the cold weather months, when the earth parts with more heat than it receives from the sun, the land becomes colder than the water; and places far from the sea—such the Panjáb and Upper Asám—are cooler than Bengal, which lies near the sea.

We are now prepared to understand why the intense heat of April and May is followed by the strong steady wind from the sea that brings the grateful rains of June and July. Up to the setting in of the rains, India is very much hotter than the great sea that lies to the southward. In Bengal indeed we have winds from the south and south-east even before the regular rains set in, and these bring us some showers; but when, in June and July, the heat of Central India, the North-West Provinces and the Panjáb has become very great indeed, the whole body of the lower part of the atmosphere from beyond the equator moves northwards towards India, and brings all the vapour that has been evaporated by the heat of the sun from many thousand square miles of ocean. This is our south-west monsoon.

Something yet remains to be explained. We have learned why the winds bring us the vapour, that when condensed produces our rains; but we have also learned that the air must be cooled in order that this vapour may be condensed; and it is not clear how this is effected; since we have seen that it is the great *heat* of India that produces the winds. Can we have great *heat* producing a wind, and at the same time this very wind cooled down so as to condense its vapour in cloud and rain? How it will be asked, can one explanation be reconciled with the other?

To answer this, we will revert to the familiar experience afforded by our fire. When it is in full blaze, the smoke, (which we now know to be carried by the heated air,) rises in a rapid stream. But it does not rise very high; perhaps as high as the tops of the palm trees, and it then spreads out and remains for a time suspended in mid air. It ceases to rise because it has already lost a great deal of the heat that caused it to ascend, and has become no lighter than the air around it. So it is with every current of air that ascends, whether it is set in motion by the-heat of a fire or by that of the sun. Some very important experiments made by Mr. Joule have enabled us to ascertain exactly the amount of cooling that air undergoes under these circumstances. It is such that if a quantity of air, as hot as it usually is about 9 in the morning in May, were to rise from the ground, it would be cooled to the temperature of ice, before it had ascended as high as Darjiling. In ascending mountains, the higher we go the colder does the air become; but not so rapidly as a mass of air that is *in motion* upwards. At Darjiling, for instance, the warmth of the air (called its *temperature*) is about half way between that of the air on the plains, and that of melting ice; and we should have to ascend to more than twice the height of Darjiling, before we should find the snow in the summer time lying unmelted on the slopes of the mountains. It is owing to the expansion that the air undergoes during its ascent, or rather to the resistance which it overcomes in thus expanding, that the air is cooled.

We have now found the explanation we sought. The highly heated air over the plains of India ascends and cools as it ascends. Air highly charged with vapour is drawn from the surface of the seas to the southward, and this, ascending in its turn, is cooled and forms dense clouds and rain. When it has risen to a great height and has got rid of most of its vapour, it turns and flows back to the south, where, descending again to the sea level, it takes up more vapour and then repeats the same circuit.

On the other hand, in December and January, when the sun is low and the surface of the land is colder than the sea; and when Australia and places south of the Equator are most heated by the sun, the air flows from us towards this heated region, in the lower atmosphere, and returns to us as a wind in the upper atmosphere. The lower current is our winter or north-east monsoon. It is so called, because at sea it really blows from the north-east, but in Bengal and the North-West Provinces it comes chiefly from the north-west or north. The upper return current, which may be called the *Anti-monsoon,* is felt on the Himálaya, and descends in the North-West Provinces and the Panjáb; and the vapour it brings furnishes their winter rains, on which the *rabi* crops depend.

In India, then, we have the wind blowing one way during four or five months of the year and in the opposite direction during another four or five months; all such winds are called *monsoons*. In the China Sea and Australia, as well as one or two other parts of the tropics, monsoons are felt much like ours, except that the directions are not the same; but in the middle of the Atlantic and the Pacific Oceans, the wind blows the same way all the year round, *viz.*, towards the equator from both tropics, and these are called *trade-winds*. In Europe again, the winds are much less regular, and at all times of year they are apt to shift from one quarter to another frequently and without much warning; so that "as changeable as the wind" has there become a proverb. Nevertheless this irregularity is only apparent and not real. There are in Europe, as in India, two principal winds, one of which blows from the cold Northern countries towards the Equator (where it is hottest); the other, the *Anti-trade*, which begins near the Equator high up in the air and blows thence towards the north and north-east, gradually descending to the earth's surface. It is this last that brings Europe most of its rain, just as our Anti-monsoon brings winter rains to the Panjáb.

In this chapter we have learned that the atmosphere that everywhere surrounds our earth is not much more than 50 miles thick, and that its lower layers are more dense than those above them, because those which are lowest are pressed upon by those above them. It consists chiefly of two gases, which when heated expand and become lighter, and when cooled contract and become heavier or denser, but which always remain gaseous, and mixed in the same proportions. It contains also water vapour, the quantity of which is always varying. This is furnished by evaporation from seas and oceans. When much cooled, it condenses and forms clouds, rain, snow and hail; or when condensed on the surface of grass, leaves and the like in the night time, dew and hoar-frost. Winds are produced by the unequal heating of the air by the sun. Heated air rises and colder air flows in below to take its place, while that which has ascended is cooled by its ascension, and so forms winds in the upper atmosphere which blow in the opposite direction to the former. At last it descends to earth, to take the place of that which has been drawn towards the heated region. In India the winds blow pretty steadily from the south, south-west, or south-east (according to the locality) during a part of the year, and from the north-west, north or north-east during another part of the year; and these winds are called the *monsoons*. The former, coming from the ocean, bring us our rains. The latter, blowing from the land towards the sea, have little vapour and bring fine clear weather. On the coast of China and that of North Australia and Africa there are also monsoons, but their directions differ somewhat from ours. On the two great oceans, the Pacific and the Atlantic, as well in on the tropical part of the South Indian Ocean, where the winds blow the same way all the year through, they are called trade winds; and in Europe where they are much less regular, this irregularity is owing to there being two principal winds, one of which is chiefly from north-east, the other from south-west, which continually displace each other, instead of one being always above and the other below, as is the case when the trade winds blow. All these movements and changes of the atmosphere are due to the heating of the sun, and to the facts that land is both heated and cooled much more quickly than water; and that the heat is most intense where the sun shines directly overhead.

CHAPTER III.

THE SEA.

In this chapter I shall have to describe things probably unfamiliar to most of my readers. But it would be impossible for them to understand much of what I shall have to say afterwards about the land, if they have not first gained some acquaintance with the nature and movements of the ocean; and fortunately it requires no great exertion of the imagination, even for those who have never seen the sea, to conceive a vast body of water, filling all the greater depressions of the earth's surface, and, as may be seen on any map of the world or a terrestrial globe, occupying very nearly three-fourths of that surface.

It is only of late years that we have gained any accurate knowledge of its depth, and even now there are immense tracts, especially in the Pacific and Indian Oceans, of the depth of which we know very little. But the third great section, the Atlantic, or rather the northern part of it which extends between Europe and North Africa on one side and America on the other, has been much more closely examined; and not only do we know pretty well how deep it is in different parts, but specimens of the bottom and of the sea animals that live on it have been brought up from depths of 1,200 and 1,400 fathoms.* The bottom of the Atlantic shows irregularities of the same kind as the land surface of

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* Depths of the sea are usually given in fathoms, each of which is equal to two yards, or four *haths*, or six feet. 1,200 fathoms is therefore 7,200 feet, or about the height of the highest part of Darjiling above the level of the sea. 1,400 fathoms is 8,400 feet, or nearly a mile and two-thirds.

Since the above was written, it has been reported, that the naturalists on board the *Challenger* have obtained a specimen of the sea bottom and the animals living on it from a depth of 3,875 fathoms, or nearly four and a half miles.

Continents. It has submarine mountain ranges, table lands, and valleys. And this we might have expected, for Geology tells us that much of what is now covered by the ocean, was at some former time dry land; and on the other hand, we know that in some of the loftiest mountains, the Himálaya for instance, the shells and other hard parts of animals that once lived on the sea-bottom are embedded in the solid rock of the mountain sides; proving to us, that although they are now high above the sea, they once formed part of the bed of the ocean. The greatest depths of the Atlantic are depressed below the sea surface, to a depth much greater than the height of the highest mountain masses that now tower above it. One large part of it is rather more than 5,000 fathoms, a depth in which if the three loftiest peaks of the Himálaya were buried, there would still be from 150 to 300 fathoms of water over their summits. It is probable that in the Southern Ocean there are depths exceeding this, but we cannot be sure of this without further measurements. We do however know that the average depth of the ocean much exceeds the average height of the land. The Bay of Bengal is very deep in some parts. On the Indian side, the depth increases very gradually, and it is probable that the deepest part lies in the east of the Bay. It shelves down very gradually too from the coast of Bengal; except at one place, about midway between the Húghli and the Megna, where there is a very deep and abrupt channel in the bed of the sea called the 'the Swatch;' the depth of which is said to exceed 2,000 fathoms, or more than two miles. This, however, requires verification.

The water of the ocean, unlike that of most lakes and rivers, is very salt; so much so, that a great part of the salt consumed in Madras (and formerly in Bengal also) is obtained from it, by collecting the water in shallow reservoirs, and allowing it to evaporate. As only the water goes off as vapour, all the salt is left behind. The salt so obtained is however far from pure. It has a more bitter taste than pure salt, owing to its impurities, which consist of salts of lime and magnesia,* with other substances, for a knowledge of which my readers must refer to books on chemistry.

The saltness of the water is nearly the same in all parts of the ocean. In the neighbourhood of any coast where a large river enters the sea, the admixture of fresh water makes it somewhat less salt; and inland seas, connected with the ocean, but almost entirely surrounded by land, are either fresher or salter, according to whether the rivers that enter them supply more fresh water than evaporates from their surface or the reverse. Thus the Red Sea, into which no river flows, and from the surface of which great evaporation is always going on, is salter than the ocean; while the Baltic, which receives many of the large rivers of Northern Europe, and which being in a cool climate, gives off comparatively little evaporation, is always very much fresher.

If it be asked why the sea is salt, we can only reply that it has probably been so from the time when it began to exist as an ocean. It is true that, from time to time, small tracts of it may have been cut off from the main ocean in some dry region and so dried up, in which case the salt has been left behind as a solid mass called rock salt. But any loss of salt that it may suffer in this way is compensated by that brought into it by rivers, all of which contain some traces of salt; and by that which the sea itself washes out of the land.

I have already spoken of the lime in sea-water. There is very little, but there would be much more, were it not that lime is continually abstracted from the water by the animals that live in it. Many of these form hard shells, which consist chiefly of a compound of lime,† and this lime is taken from the water; there are a kind of animals called

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* My readers who do not know chemistry, will still understand that lime is the white substance eaten with pân, and made into mortar for building; and one salt of magnesia is known to all who have ever taken a dose of Epsom salts.

† In parts of Bengal the lime eaten with pân is generally made by burning the large shells collected in the salt lakes of the Soonderbuns. In Madras large quantities of sea shells are collected fcr the lime used to stucco the interiors of houses.

corals, the greater part of whose body consists of a hard skeleton of lime. They do not move about, but live, almost like plants, fixed in the same spot; and when they die, their skeletons remain, or being broken up by the waves and recemented, form masses of limestone which serve as supports for others to grow upon. In this way vast masses of stony substance accumulate, and new rocks and islands are formed. The Maldives and Laccadives to the south-west of India are entirely islands of this class.

In the neighbourhood of the coast the color of the sea water is generally green; this is not the true color of pure sea water, but is owing to the mud brought into it by rivers and that washed from the coast. In mid ocean, the color is a pure deep indigo blue, and the water so transparent that if a white plate be thrown into it, it can be seen after it has sunk many fathoms below the surface. The surface of the sea is seldom quite smooth; this is the case only when there has been no wind in the neighbourhood for two or three days. Most frequently it is raised in waves, which roll along in the direction of the wind, or are simply propagated by the water from some distant place where a strong wind is blowing. These latter are spoken of as the *swell* of the sea; and the rolling of ships as they sail over it, is to many persons, who are unused to it, peculiarly unpleasant, producing sickness. When these long waves reach the shore, such a shore for instance as extends along the face of the Súndarbans or the coast of Orissa and Madras, they become higher, and the crest curling over breaks in a mass of foam, which makes it dangerous for boats, except such as are built with planks sewn together, like the Masúlah boats of Madras. Such waves are termed *breakers*, and in storms they have great destructive power, and soon dash to pieces and break up any ill-fated ship that may have been driven on the coast, and so become exposed to their impact. On a coast such as that which extends along the Indian side of the Bay, where the land is almost everywhere low, the coast is not much destroyed by the action of the waves, but on rocky coasts where the edge of the land is high above the sea level they pound and break down the exposed face of the rocks and sweep away the abraded material, leaving a cliff, such as is shown in the subjoined woodcut.

Fig. 2.—A Sea Cliff and Beach.

The waves of the sea subserve one very important purpose, *viz.*, they facilitate the *aëration* of the water; that is, they help the air becoming dissolved in the water; without which fish and most other animals that live in water would be unable to breathe.*

In the introductory chapter, we learned that the greater part of the mud that renders our rivers so turbid is carried down into the sea with the water; and I have now shown that, in addition to this, a great deal is carried away from certain coasts which are being eaten away by the waves. All this sinks gradually to the bottom; but before it finally settles, it is often carried many hundreds of miles by those movements of the water of which we have yet to speak. However, sooner or later, it settles down, and forms new layers of mud and sand on the floor of the ocean. In deep seas, these accumulations of necessity form very slowly; but they accrete more rapidly near the mouths of large rivers. and certain coasts that are wasting rapidly. The dead bodies of fishes and other marine animals, sinking to the bottom, are sometimes buried in this mud and sand; and the hard parts, such as shells and bones, are thus frequently preserved. Ages afterwards, when, by some of those changes that our earth is always undergoing, these layers of mud and sand have become converted into stone, and being upheaved, once more form part of the dry land, such remains, now termed *fossils*, are discovered by Geologists, who learn from them what kind of animals lived in the sea, it may be thousands and hundreds of thousands of years before. Sometimes, but more rarely, the bodies of land animals and the leaves and branches of plants are embedded in the same way; but these are more common in similar accumulations that are formed in lakes or in the *deltas* of great rivers, such as that on which we live in Bengal. In another chapter we shall see that by diligently collecting and examining remains of this kind we have learned that the animals that live on the earth now are not like those that used to live there in former times; and that all of them have changed, not once only, but many times in succession.

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* *Most*, but not *all*. Whales, porpoises, seals, dugongs and all such animals as suckle their young, also turtles and sea-snakes, breathe air, for which purpose they come occasionally to the surface.

The sea is never at rest. Not only is the surface stirred by the wind, but the whole mass of the ocean is moved by tidal and local currents. Tidal currents flow first one way and then in the opposite direction, changing each way twice in about 25 hours, and producing a rise and fall of the water level twice in the same period. The second, in most parts of the ocean, run in the same direction with but little variation all the year through; and the result is, that the whole water of the ocean is constantly but slowly moving from one part of the earth to another. The causes of these movements may be understood with a little careful attention.

I have said that the tide rises and falls twice in about 25 hours; those who live on the banks of the Húghli or the Megna, or any of the large rivers of the Súndarbans near the sea, must be familiar with this as a fact of life-long experience. This period of 25 hours, or more exactly 24 hours, 54 minutes, is exactly that between the time that the moon is seen at the same place in the sky on two successive days; a fact which would at once suggest that the moon is in some way connected with the tides. Now if the reader bears in mind what we learned a short time since, about gravitation, he will find little difficulty in understanding what this connection is. I must only add one fact, which I have not mentioned before in order to avoid complexity at the outset. It is this; that the farther any two bodies are from each other, the less is the pull they exercise on each other; and in such measure, that if the centre of the moon were twice as far off the centre of the earth as it is, she would pull and be pulled by the earth with only one-fourth the actual force; if at three times the distance, with only one-ninth of that force; if at four times the distance, with one-sixteenth, and so on.*

Now let us see what consequence follows from this, if we suppose the earth to be a rigid ball; that is, one, the shape of which remains unaltered, however it may be pulled; while it is covered with water, which flows easily in any direction: and for the sake of greater simplicity, we will assume first of all that the earth is completely covered by water, as represented in Fig. 1. Plate I. When the moon is in the position represented in Fig. 2 the water on the side *a*, nearest to the moon, will be pulled more strongly than the rigid earth *c*, because it is nearer; and will be heaped up at *a*, being drawn away from all that part which lies towards *d* and *e*. Thus high water will be produced at *a*. In the same way, and for the same reason, the rigid earth *c* will be pulled away from the water at *b*, and another pile of water, producing another high tide, will be the consequence. At *d* and *e* the water will be low, so that two high tides and two low tides are produced at the same time. Now as the earth revolves on its axis which we may suppose to be represented

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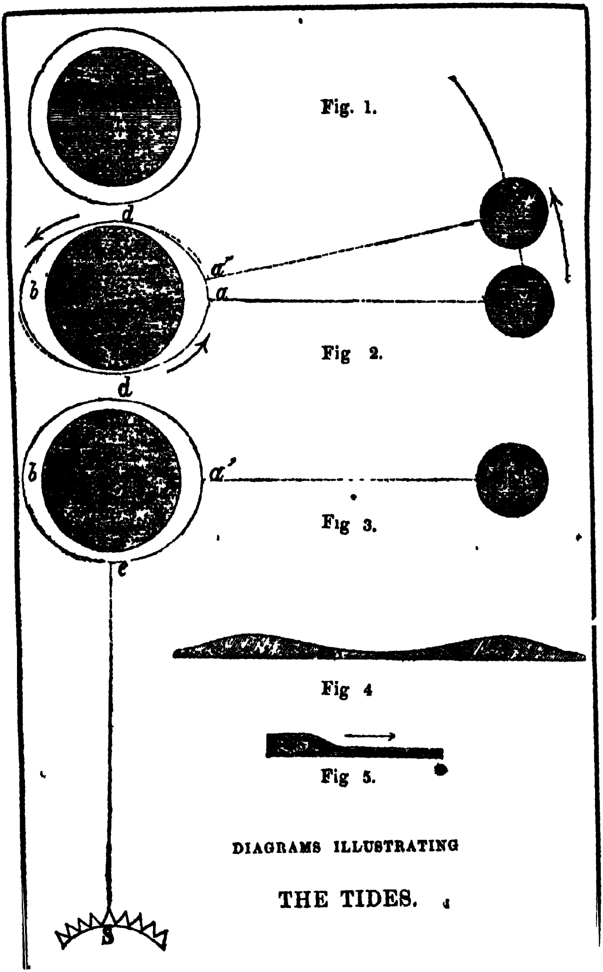
* Common arithmetic shews that the denominators of these fractions are the squares of the figures expressing the distance; so that the law of gravitation is expressed by saying, that the force is inversely as the square of the distance of the two bodies.

PLATE I.



DIAGRAMS ILLUSTRATING

THE TIDES.

by a line, at right angles to the plane of the paper, passing through the centre of *c*, every point on the earth will be successively in the positions *a d b e a;* and if the moon remained in the same place at M, every place on the earth would have high water twice and low water twice in twenty-four hours; that is to say, while the earth completes one revolution. But in the meantime, the moon has moved in her own orbit towards M′, so that by the time that the place starting originally from *a* is again opposite the moon and therefore has high water on the second day, the moon has reached the position M′. This whole journey is completed in 24 hours 54 minutes.

The rise and fall of the tide is not the same in amount from day to day. Twice in every lunar month the tides rise to their highest point at high water, and fall to their lowest at low water: these are termed *spring tides.* These highest and lowest tides occur at or a little after full and new moon. The intervening tides, in which there is the *least* difference between high and low water, that is, when the rise and fall are least, are called *neap tides.* At Calcutta, at high spring tides, the water rises and falls about 15 feet between high and low water; and at neap tides only about 6 feet. This variation is owing to the fact that the sun produces tides as well as the moon; but since the sun is greatly more distant, the diameter of the earth is very small in comparison with that distance, and the difference of the sun's attraction on opposite sides of the earth is less than in the case of the moon. The sun's tides therefore are less than the lunar tides.

Spring tides are produced, when the sun and the moon are both on the same side of the earth, that is at new moon; or when they are on opposite sides, *viz.*, at full moon. When in either of these positions, the solar and lunar tides coincide. Let us suppose, for instance, that in Fig. 2 the sun is far away to the right beyond M, then both sun and moon produce high water at *a* and *b;* and the same thing will result if the sun be opposite M, to the left of the figure. But if, as in Fig. 3, the moon is at M and the sun at S, (or in that or the opposite direction,) while the moon produces high water at *a* and *b* as before, the sun causes high water at *d* and *e*. The tide that results is then only the difference of the solar and lunar tides, instead of being their sum.

In this description I have supposed the earth to be covered uniformly with water, for the sake of simplicity. But we know that, in reality, the ocean is continuous all round the earth only to the south of the great Continents, while three independent oceans extend into the northern hemisphere. This very much complicates the phenomenon of the tides, because one great tidal wave cannot travel from one ocean to another round the earth: a kind of independent tide is produced in each of the great oceans, at the same time that the tidal waves, that circulate round the earth in the Southern Ocean, are propagated up each of the oceans in succession; in much the same way that the waves produced by throwing a stone into still water are propagated in circles to a distance over the surface: and these propagated waves, termed *free* waves, travel the faster the deeper the ocean is. But notwithstanding all the irregularities that arise from the inequalities of the earth's surface and those of the ocean bed, with few exceptions, every place on the shore of the ocean or on large rivers near the ocean has two tides every day. In places around the Atlantic these are generally equal; but in India, one is generally higher than the other.

I have spoken above of the *tidal waves*. If a ring like the unshaded part of Fig. 2 which is much like an O, being wider at the sides than at the top and bottom, be cut out of some flexible substance, (such as sheet Indian rubber,) then cut across at *d* or *e* and pulled out straight, it will have the form of Fig. 4, which represents two waves, each of which in its original position on the earth extends half round it. This is really the character of the tides; and if, as we at first supposed, each wave could travel freely round the earth, there would be two and only two such waves in existence at the same time. But since the tidal wave that is propagated from the Southern Ocean northward is retarded by friction on the sea bottom, before one has completed its journey into the extreme northern bays of the ocean and into its river estuaries, such as the Húghli and Megna, a second, third or even a fourth may have started from its place of origin in the South Sea. Each such wave becomes higher and shorter as the sea becomes shallower; and when, at last, it reaches some very shallow estuary, such as those of the two rivers I have mentioned, the advancing wave sometimes is so retarded and piled up as to form a visible wave, as in Fig. 5. This is then turned a *bore*. In the shallow parts of the Megna, boats are sometimes upset by this bore, and by the rush of water that immediately succeeds the sudden rise of the river's level.

Since a large body of water must flow to a place to raise the level from that of low to that of high water, and the same quantity flow away from it to lower the level again to that of low water, the tides keep the sea always in motion. Indeed the motion affects every part down to the bottom; and where the sea is shallow, the currents thus produced are sometimes very rapid. Such a current is termed a *race*. These tidal currents stir up and carry with them the fine sediment of which I spoke in the earlier part of this chapter, and thus it is sometimes carried away and finally settles in some deep part of the sea, far from the river that originally brought it down. It is not improbable, though it cannot be considered certain at present, that the great channel-like depression in the bottom of the Bay of Bengal, mentioned above[*] as 'the Swatch,' is swept free from sediment and kept open, by the ebb currents that carry back to the south the water that has been brought to the north of the Bay during the flood tide.

Tidal currents are not the only currents by which the oceanic waters are kept in motion. Whenever a wind blows steadily for some days, the surface water is driven before it. Now in the neighbourhood of the equator the trade winds blow constantly in the same direction, and thus set in motion a current, which, at first little more than a *drift* of the surface water, becomes deeper as the action is continued, and eventually is resolved into a steady westward motion of the upper layer of the ocean water. Such is the case in the equatorial part of the Atlantic Ocean; the waters of which are thus impelled through the Caribean Sea into the Gulf of Florida. Here their westward motion is arrested; and after making the circuit of the Gulf, they

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issue between the promontory of Florida and the Island of Cuba, as a deep steady current, flowing at the rate of 4 miles in an hour, in a northerly direction, parallel with the coast of the United States. This current is famous under the name of the *Gulf Stream*.

On reaching Cape Hatteras it turns eastwards, spreading out and coalescing with the north-easterly drift of the surface water, generated by the south-west winds of the North Atlantic. Thus, water which has acquired a high temperature in the Caribean Sea and the Gulf of Florida, is carried to the west coast of Europe, and by the warmth which it communicates to the air above it, makes the climate of the British Isles, France, Denmark and Norway warmer and more genial than that of other countries under the same latitudes.

This circulation of the ocean waters is assisted by another cause. Cold water is heavier than warm water, for the same reason that cold air is heavier than warm air (see page 24). This is rigorously true in the case of salt water, (though not so in the case of fresh water). The sea water of the Polar regions, which is exceedingly cold, therefore sinks; while that which is somewhat warmer flows in from the surface of the sea in lower latitudes, becomes cooled in its turn and sinks. The cold water which has sunk, on the other hand, flows very slowly towards the equator, and gradually acquiring warmth as it proceeds on its journey, eventually rises to the surface, is heated more highly under the torrid sun, and returns to Arctic and Antarctic regions, in the manner already described in the case of the North Atlantic. There are similar currents in the other oceans, but few are so well known as the Gulf Stream, and indeed few are so important in their effects.

In the Bay of Bengal the currents change with the monsoons. During the south-west monsoon, and indeed as long as south-west winds blow on the coast of India, (which is during the greater part of the year,) a strong current runs up the coast, from south to north; while in the winter months, when the wind is from north-east, the currents run less strongly from north to south. These currents have had an important influence on the shape of the coast, as we shall see when we have to speak of that subject. It is partly owing to them that the east coast line of India is so straight as it is seen to be on the map, and that, as a consequence, it is so devoid of good harbours for ships.

We have learned in this chapter that the sea is a vast body of salt water, in some parts very deep, deeper than the loftiest mountains that tower above its surface, and constantly kept in motion by the action of the tides, the winds, and its own heating and cooling. It is the home of myriads of animals; some of these, like fishes, swim freely through it; others, like crabs, prawns and the creatures that produce shells, (of which the common little cowrie is familiar to all of my readers,) creep over the bottom; and others again, like corals, live firmly fixed to the bottom almost like trees and plants, but are nevertheless true animals. These all breathe the air which is dissolved in water; and the waves of the sea, caused by the winds, are the agents by which the air becomes so dissolved. There are also vast quantities of plants growing in the ocean, some growing on the bottom like land plants, others floating freely in its waters. The remains of both animals and plants, when they die, frequently sink and become covered up by the sand and fine sediment, which is partly brought down by rivers, partly washed from the coasts, being worn away by the action of the breakers, and distributed far and wide by marine currents.

We have also learned that the tides of the sea are low waves of vast extent produced by the attraction of the moon and the sun, and that at full moon and new moon the two sets of tidal waves coincide and produce the highest and lowest tides, called spring tides; while at the moon's quarters when the high water of the lunar tides coincides with the low water of the solar tides, and *vice versa*, the rise and fall of the tide is least. The rise and fall is increased where the sea is shallow, and becomes greatest in shallow bays and the mouths of large rivers; sometimes becoming so piled up as to produce a bore.

In the preceding chapter we learned that the surface of the sea is always giving off vapour under the heat of the sun, which is carried away by the winds and eventually forms cloud and rain; that owing to the slowness with which the sea water becomes heated and cooled, there is much less difference in its warmth in the day and in the night, or in summer and winter, than there is in the case of the land: and hence islands and places on the sea coast have a mild climate, never so hot or so cold as places under the same latitude in the interior of Continents. Where warm currents like the Gulf Stream of the North Atlantic prevail, bringing warm water into a colder region, they help to make the climate warmer and more genial, and it may be added that cold currents flowing towards the equator on the other hand, by cooling the air, make the climate more rigorous than it would otherwise be. Such, for instance, is the case of Labrador in North America.

CHAPTER IV.

HOW ROCKS ARE FORMED.

If the reader has appreciated the spirit of the teaching of the previous chapters; if he has clearly apprehended the great fact that the atmosphere, rivers and sea waves are all slowly working a change on the outline and surface of the land; he will no longer look upon the existence of continents, islands, mountains and plains as dry ultimate facts, respecting which, when he has learned their positions and names, there is little more that it concerns him to know; but he will see that every single feature of the surface, every river, channel, hill and plain, every detail of the form of a coast line must have a history of its own, stretching back, it may be, into an unfathomable past; and that each of these is the *result* of a vast number of causes, many of which he may see in operation around him. They are then no mere poetic fancies, but simple scientific truths that are embodied in the words of Tennyson:

> Where rolls the deep, there grew the tree.
> Oh earth, what changes hast thou seen!
> There, where the long street roars, hath been
> The stillness of the central sea.
>
> The hills are shadows, and they flow
> From form to form, and nothing stands;
> They fade like mist, the solid lands,
> Like clouds they make themselves and go.

But our present business is not only with the broad fact, that these things are changing and have always been changing: we have to learn in what way and by what causes they have become what they are; and we shall find that, though there is no written chronicle to appeal to, to tell us their past history, still by noticing their forms and structure, and by examining the materials of which they are built up, very much may be learned with almost the same degree of certainty, as if we had witnessed the whole process from the beginning.

Let us see first of all of what materials the land is made; and let us start with the plains of Bengal. The surface soil alone will not tell us much. It is generally a mixture of fine sand and clay termed *loam*, and as we learned in the introduction, it is very much like the *silt* or fine sediment that settles from muddy river water when it is allowed to stand till it becomes clear. But when a new tank is dug to a depth of 20 or 30 feet, the newly exposed earth slope will generally be found to exhibit layers of different kinds of earth. It may be that the first six or 8 feet from the surface, perhaps more, is a layer of loam like that seen at the surface; then perhaps comes a layer or *bed* of stiff clay; next, it may be, a layer or *bed* of sand; and very often at a depth of about 20 or 30 feet comes a thin layer of black looking material, which, if it be dried and then thrust into a fire, will be found to lose all its blackness, and in great part will be burnt away. Such a layer is found almost every where in and about Calcutta, and in many parts of the 24-Pergunnahs and Jessor. It chiefly consists of the decayed remains of plants and is sometimes spoken of as *peat*. But very often in this dark layer or *peat bed* (as it is termed by Geologists) and below it, are found unmistakeable stumps of trees, with the roots attached, exactly in the position in which they grew, but now buried perhaps 20 or 30 feet below the surface; at such a depth indeed, that if all the layers above them could be removed over the whole surface of the country, the sea water would come up and actually cover them. The

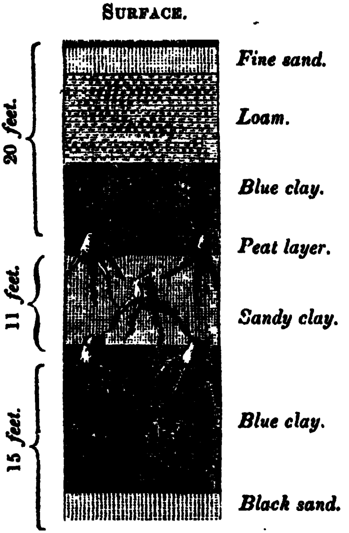

Fig. 3.—SECTION OF GROUND EXPOSED IN A TANK AT SEALDAH, CALCUTTA.

annexed woodcut represents the beds thus actually met with in excavating the large tank near the Sealdah railway station in Calcutta: the tree stumps, which are there represented, were found on examination to be those of *Sundri* trees, such as are abundant at the present day in the forests of the Súndarbans. The level at which these tree stumps occur once have been the surface of the ground, and the earth now accumulated above them has since been deposited by the river waters. Occasionally, the decayed shells of snail-like animals, such as may now be found living in any tank or jhíl, are met with in the clay, and prove therefore that it has been deposited from fresh water. Many years ago, a well was sunk in Fort William at Calcutta, to a depth of 481 feet; the whole distance through successive layers of sand and clay, peat and pebbles. At a depth of 350 feet, part of the bony shell of a fresh water tortoise, such as are abundant in the Ganges at the present day, was met with. Further down again, at 380 feet, was a layer of fresh-water shells, and then a bed of decayed wood, showing that there was once a forest growing on ground that is now 380 feet below the surface; but which must at that time have been the surface and as high up as the present surface of the Súndarbans. The land, then, must have sunk at least 370 feet since the time when these trees grew, and all the enormous mass of earth now covering them must have been deposited from the rivers. From observations like these, we learn that all these broad plains of Bengal have been formed of the sand and clay brought down by the waters of the rivers; and such is the character of the great Gangetic plain of the North-West Provinces, as well as the similar plain of Orissa, that of the Godáverí and other great rivers.

Let us now make an ideal journey to the Khási Hills in Sylhet. Up to the foot of these hills we find the plains are very much like the rest of Bengal, except that the jhíls are larger and more numerous; and if we make our journey in the rains, we shall probably find the country flooded; but when, leaving the swampy plain, we began to ascend from Tharia Ghat by the road to Chera Púnji, we meet with hard stone and rocks of several kinds not seen before. A little way up the ascent, the rock is like sand hardened into stone, and at one place, diligent search will enable us to discover embedded in this stone (called *sand stone*) shells of several kinds. They are not like those met with in the clay beds around Calcutta, but rather like shells of animals that live in the sea; not indeed identical with any that *now* live in the sea, but so much like them, that we can entertain no doubt that we have before us the remains of marine animals. Leaving this place and continuing our ascent, we traverse a great mass of sandstone all formed in layers,* sometimes horizontal, sometimes highly inclined; and at the top, close to Chera Púnji, we see, on the left, a little hill containing a bed of coal, and consisting chiefly of another kind of hard rock, which when burnt forms lime, and is therefore called *limestone.* This limestone too contains shells, but they are not like those found in the sandstone at the bottom of the hill; nor, with a few exceptions exactly like any now living. Like the former, however, they resemble marine shells, and we infer therefore that they were formed by animals that at one time lived in the sea. But if so, great changes must have taken place since these creatures lived, for they are now more than 4,000 feet above the sea. Thus, then, we learn from the shells they contain, that the rocks forming some of our hills have been formed in the sea, in the manner described in the last chapter, and that the old sea bottom, by some means or other, has been lifted up so as to form a lofty chain of hills.

We have thus learned that all the rocky or earthy materials forming the plains of Bengal and the part of Khási Hills that I have just described, have been deposited from water, in some cases from fresh, in others from sea water, and that they are all formed in layers termed *beds* or *strata.* All such rocks (for the term *rock* is applied by Geologists indiscriminately to sand and sandstone, loam, clay and limestone, in fact to all earthy or stony masses whether soft or hard,) are termed *stratified* rocks; and this bedded or stratified structure is an indication that such rocks have been formed in water. From the fact that they are formed of *sediment,* or that which had settled down from muddy water, they are also called *sedimentary rocks.*

See woodcut Fig. 5, page 52.

Next let us suppose we make a journey up to Ránigani to the north-west of Calcutta, or still better to the Baráckar station some twenty miles further on. The surface here is no longer flat as in Lower Bengal, but undulating; and every stream and river flows at the bottom of a depression, the surface sloping down gently towards it from some distance on either side. This surface is generally covered with soil of a yellowish color, unlike that of the rice fields of Jessor and Dákha, and not so fertile. But this soil is of no great thickness; wherever an excavation is made to the depth of a few feet, and everywhere in the banks of the smaller streams or nálás, where their channels are cut deeply into the ground, hard rocks are exposed, which we readily recognise as sandstones. In some places also, we meet with layers of clay, or hard clay breaking up in thin slabs, termed *shales*, and occasionally beds of *coal*. All these are stratified, like the rocks of the Khási Hills; and (with the exception of the coal, which is the remains of an ancient forest,) have been formed in water. But if we go a few miles to the north beyond the Adjai, or to the south a little beyond the Damúdah, or up the Great Trunk road for 3 or 4 miles beyond the Baráckar river, we come upon rocks of quite a different character. These latter are very hard and compact, frequently containing little shining black or grey scales of a mineral called *mica*, and with no distinct stratification. This is a *crystalline* rock. It never contains the remains of animals, whether of land or fresh water, and sometimes it looks as if parts of it had at one time been actually liquid, or at all events soft, so that it has been squeezed and contorted in a very irregular manner. This rock is termed generally *Gneiss*; and there is reason to believe, that though at some former time it may have been a stratified rock, it has since been heated and so acted upon by heated water under great pressure, that all the materials of which it consists have been undergone a chemical change, and have been rearranged. Rocks like this are very common in India. Except the soil of the surface, no other rock than varieties of Gneiss are to be met with over the greater part of Southern India, and the same is the case in the western part of Orissa (in the Garhját states) and in Chutia Nágpúr and Hazáribagh.

The greater part of the Himálaya is made up of rocks more or less similar, and so is all the northern part of the Gáro and Khási Hills. Whenever a series of stratified rocks can be followed down to their lowest layer, as a rule the bottom layer is found to rest on this *Gneiss*. From the fact that Gneiss has probably at one time been stratified and subsequently greatly altered or *metamorphosed*, a term which means much the same thing, it is termed a *metamorphic* rock.

These two classes of rocks, the *stratified* or *sedimentary*, and the *metamorphic*, are much the most common. But there are yet two other classes, termed respectively *volcanic* and *granitic* rocks, which have originated in a different way. In the Rájmahál hills the former of these occur, apparently in layers, interstratified with true sedimentary rocks, but their inner structure is not stratified. The stone of which they consist is generally hard and heavy; and sometimes contains rounded cavities which have been afterwards filled with minerals of a different kind. At some former time, it issued in a liquid molten state from the interior of the earth and flowed over the surface, or perhaps over the bottom of some lake; after which, being cooled by exposure to the cold air or water, it became solid, and so formed a layer as we now see it, on the top of which layers of sedimentary rock were afterwards formed in the way I have already described. Sometimes rocks of the same kind are met with in a different kind of arrangement. A very good instance may be seen between the Núnia nálá and the Assansol Dâk Bungalow about half way between Ránigan j and Baráckar, on the Great Trunk road. At this place, a line of rounded masses of very hard stone, very different from the sandstones and other stratified rocks of which I have spoken, may be traced across the country for many miles, sometimes forming a rocky ridge above the general surface, at other times nearly covered by the soil and only indicated by rounded blocks partly protruding from it or quite loose and resting upon it. This marks the top (or *out-crop* as it is technically termed,) of a *dyke* of volcanic rock. If all the sandstones and coal beds that lie on either side of it were cleared away, it would be seen to stand out like a gigantic wall, and however deeply the excavation might be carried, the bottom of it would never be reached. In fact it reaches far down into the depths of the earth, where it is connected with some large deeply seated mass of volcanic rock; and at some former time, it must have issued in a molten state, filling a gigantic crack more than 20 miles long, and, where it crosses the Great Trunk road, 120 feet across. Many other similar dykes may be seen about Rániganj, though not so large as this. Wherever the sandstones or the coal are in contact with these dykes, the former are seen to be hardened and altered as if they had been baked; as indeed they have been by the intense heat of the dyke when molten.

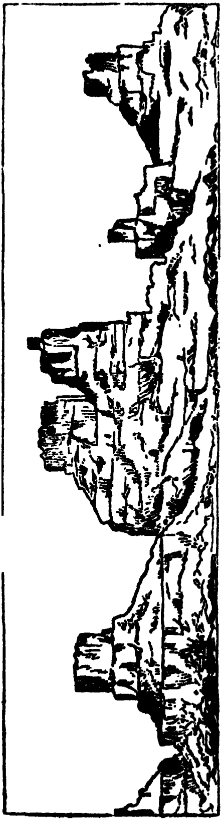

Fig. 4.—TRAP HILLS NEAR NÁSIK.

In Western India rocks of this kind are met with, exceeding in extent and magnitude, as far as we know, any similar mass elsewhere in the world. All the country between Nágpúr and Bombay is covered with enormous sheets of dark colored rock, which at some former time have been poured out in a molten state over the country, from volcanos that now no longer exist. The hills formed by them have a very peculiar appearance, being frequently flat on the top and with very steep sides. Sometimes the sides, when seen from a distance, appear to be broken by terraces, the whole looking like a series of gigantic steps, as shewn in the annexed woodcut. From this peculiarity, which is owing to the manner in which this part of the country has been formed, *viz.*, by successive outpourings of rock of unequal degrees of hardness, such rocks are often termed

Trap,* a name derived from the Swedish word signifying a stair, or step. The term is a very useful one and is applied to rocks of the kind when they form dykes, as well as when they present the step-like arrangement. Thus the dyke spoken of above would be called a *Trap-dyke*.

There are other kinds of rocks having their origin in volcanos, but as they are of less importance than these *trappean* rocks, we may defer their description for the present.

The origin of *Granitic* rocks is in so far similar to that of volcanic rocks, that, like these latter, they have been in a liquid state in the interior of the earth; and while in this condition they have been forced into other rocks (not themselves liquified, but perhaps only softened,) breaking into them and through them, and afterwards becoming cooled and solidified very gradually. But there is this important distinction. While trappean rocks are often poured out over the surface, granitic rocks are never met with in such a situation; and there is reason to believe that they have in all cases cooled down very slowly, while yet deep in the interior of the earth. Long afterwards, they have become exposed at the surface, when, by the action of seas and rivers, together with those movements of the earth's crust which we have yet to speak of, either the whole of the rocks originally covering them have been worn away, or they have been thrust up in some great mountain chain and exposed at its deep fissures. Hence it results that they are very frequently met with in mountain chains, such as the Himálaya, generally breaking into rocks of the *metamorphic* class. In appearance, and in the minerals that compose them, they much resemble these latter, except that they rarely show any trace of that layer-like arrangement of the minerals, termed *foliation*, that is very common in gneiss. Sometimes, indeed, it is almost impossible to tell one of these rocks from the other; for gneiss, when very highly *metamorphosed*, become to all intents and purposes a granite. But true gneiss is never intruded into other rocks, as are volcanic rocks and granite, and this fact, and generally the peculiarity of its mineral arrangement, are characters by which the last may be distinguished.

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* *Trappa*, Swed.; *Treppe*, German.

All rocks then, with insignificant exceptions, belong to one or the other of these four classes,—*stratified* or *sedimentary*, *metamorphic*, (which are stratified rocks altered by heat and the action of heated water in the interior of the earth,) *volcanic* and *granitic* rocks. All sedimentary rocks have been formed on the bottoms of seas and lakes, while those of the last two classes have proceeded from great depths in the interior of the earth. We know a great deal more about the way in which sedimentary rocks are formed, and under what circumstances it results that sometimes clay, sometimes sand, and sometimes limestone forms their material, than we do in the case of volcanic and granitic rocks; for we can to some extent watch what goes on in seas and rivers, and even obtain specimens of the bottoms, but we cannot penetrate to those depths in the interior of the earth at which rocks are melted and metamorphosed. But in some respects the former are the more interesting to us, because we find buried in them, and still recognizable, the remains of creatures that have lived in past times, and thus we learn a great deal of the wondrous changes that animals and plants have undergone, ages before man existed.

Not only do we thus learn that the whole animal kingdom has continually been subject to changes as great as those of the plains and seas that they tenanted, but we learn also the order in which one kind of animal has succeeded another in past time. It is not difficult to understand how this can be discovered. The case of the limestone and the sandstone of the Khási Hills, already described, will afford us an excellent illustration of the method. The annexed woodcut represents a Geological section of the Khási Hills,—that is, what would be seen, if the hills at Chera Púnji were cut through from north to south so as to expose the arrangement of the rocks that form them; *b* represents the position of the sandstone containing marine shells, while *a* represents the limestone. The sandstone here must clearly have been formed before the limestone, because the latter rests on the former; and therefore the creatures whose remains are found in the sandstone must have lived long before those, the shells of which are embedded in the limestone. In the interval, a mass of sand not less than 1200 feet thick (since hardened into stone,) must have been deposited on the spot. How long this would take to accumulate we cannot well tell, but it must have been a very long time indeed; for it had all to be worn away from the land of that day, by the action of the seas and rivers, and this is far from being a rapid process. Moreover, it would appear that, in the interval, nearly the whole of the shelled animals and other creatures inhabiting the sea had died out, and had been replaced by others differing from them, and this we have every reason to believe is a process of extreme slowness. It is therefore, beyond doubt, that a very long period, certainly many thousands of years elapsed, while these great beds of sandstone were being slowly piled up on the bottom of the sea.

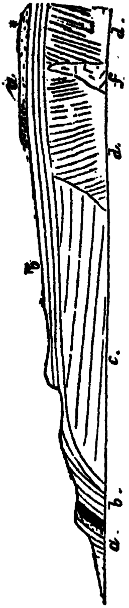

Fig. 5.—Geological Section of a part of the Khasi Hills.

"By comparing together the animal remains, such as shells, bones and the like, that are met with in sedimentary rocks in different parts of the world, it is found that each kind of animal has continued to exist for a certain time, in some cases longer, in others shorter; and that when a kind has once died out and become extinct, it does not reappear at any later epoch. Consequently their remains, termed *fossil remains* or simply *fossils*, characterise definite periods of the earth's history, and when a considerable number of identical fossils are found associated together in sedimentary rocks in two widely distant countries, they indicate that these rocks were formed about the same time; at all events within such a limited period, that the animals, whose remains are found in both, continued to live during the interval. Such rocks are said to belong to the same *formation*. Thus we have learned that the sandstones of the Khási Hills belong to about the same period of the earth's history as the chalk which forms the cliffs of the English counties, Kent and Sussex, and which is imported into India for writing on the black boards of our school rooms and for many other purposes. This formation is called the *cretaceous formation* from the Latin word signifying *chalk*. There are other deposits of the same age in Trichinopoly and South Arcot, in Southern India, and again at Bágh, not far from Indore; but these are sands, gravels, clays or limestone, in no case chalk. The summits of certain of the mountains bordering the Spiti valley in Tibet are also composed of a limestone of the cretaceous period; and since this rock was formed on the bottom of the sea, it is clear that these gigantic mountains have been lifted up or *upheaved* since the cretaceous period. There are but very few creatures still existing, of those that lived in the cretaceous seas; and these few are such as live in very deep water.

In like manner, the limestone containing fossils at the top of the Khási Hills, close to Chera Púnji, is found to be of about the same age as a portion of the Hála range in Sind; as certain limestones that occur in the Pyrenees and the Alps of Europe; and as the gravels, clays, &c., on which both London and Paris are built. And the coal beds of Ráníganj are known to be of the same age as those that occur in the Narmada valley, near Chánda, in the Central Provinces, and in the Nizam's territory in Southern India; and lastly, as the coal of Newcastle in Australia. These are far more ancient than any of the formations above spoken of.

It is not in general so easy to ascertain the age of a volcanic or granitic rock as that of a sedimentary rock; nor can we very well learn when any particular rock was metamorphosed. Still in some cases this may be discovered with considerable precision. Of the trap-dykes at Ráníganj and Barákar we know at least that they are of later age than the coal-bearing rocks that they have broken through, but it is as yet doubtful to *what* later period they belong. The great trap-flows of Western India partly cover rocks of cretaceous age, and must therefore have been poured forth after these were formed. Moreover, near Broach and Surat, certain rocks rest upon them that are known by their fossil remains to be of the same age as the Chera Púnji limestone, and these contain broken fragments of the trap rocks: therefore the trap rocks are older than these. In this case the age of the trap rocks has been determined therefore with considerable exactitude.

Summary.—In this chapter I have described the principal classes of rocks that constitute the superficial part of the earth; of the interior we know very little, and that little will be more conveniently noticed later on. We have seen that most of the rocks have either been formed very slowly by deposition at the bottom of the sea, or in lakes and river inundations; the materials being the mud, sand, &c., that are worn away from the surface of the land; or that they have been softened or molten or otherwise rendered liquid in the interior of the earth, and when liquid have either been simply forced into other more solid rocks, or poured out over the surface, (sometimes indeed over the sea-bottom), and have then gradually cooled and become solid. According to their mode of origin, they may be spoken of as *aqueous* or water-formed rocks, or as *igneous* rocks, by which latter term is meant that they have been brought into their present condition by the agency of heat. Rocks which have been originally formed by water, but have been subsequently softened and altered by heat, without being actually liquified, are termed *metamorphic*. The *stratified* and *metamorphic* rocks form by far the greater part of the earth's surface, and indicate that every part of the earth has at some time or other been covered by water. *Stratified* rocks are distinguished by their bedded or stratified structure, *igneous* rocks by their being intruded into other rocks, or, in the case of certain volcanic rocks, poured out over the surface. They are also to be recognized by their mineral structure, but this is a matter which can only be studied in the rocks themselves, mere description being useless. For this reason I have not attempted to describe the different varieties of each class of rocks, but have only referred to some of the commonest stratified rocks, such as clay, sand, sandstone, limestone, &c. Every opportunity should be taken by the student to obtain specimens of these, if he cannot visit and examine them in their native sites, but he must bear in mind that this, like all other parts of Geology, can be properly studied only in the field.

In the sedimentary rocks are found the remains of creatures and plants that have existed in past times; and by studying their forms, and comparing them with existing animals and plants, a wonderful history has been opened up to us. From them we have learned that man was not always a denizen of the earth; but is, on the contrary, only one of the most recent of its inhabitants; and while many of our most familiar animals are little more ancient than he is, others have existed from very distant periods. How or when the earth began to be, Geology can never tell us; but we know that everything on its surface has changed again and again. As one kind of creature has died out, others have appeared and replaced it, and this has gone on continuously and without a break, from the very earliest times of which we know anything. In this grand history, the notion of *time* presents itself under a new and unfamiliar aspect. Before the unmeasured past that Geology reveals, our well known divisions of months, years and centuries, sink into insignificance. We no longer speak of the life of an individual but of that of a *species* or kind of animal; and an *epoch* in Geological language means the duration of a whole creation of living things. As in Astronomy, when we try to express in numbers the distance of the fixed stars, the figures are such as convey no distinct meaning to our minds; so in Geology, the vast periods that have rolled away before man appeared, transcend all our powers of conceiving them.

The feeling of the learner as he gazes for the first time on some old Silurian crag, and tries to realize the story told in its contorted strata and rugged surface, abraded by the breakers and then half buried beneath the gravels of an only less ancient Devonian sea, is such as Playfair has recorded, when, standing on a rocky headland of the Berwick coast, Hutton traced out the meaning of the stony chronicle before them. "The mind," he says, "seemed to grow giddy by looking so far into the abyss of time; and while we listened with earnestness and admiration to the philosopher, who was now unfolding to us the order and series of these wonderful events, we became sensible how much further reason may sometimes go, than imagination can venture to follow."

CHAPTER V.

THE INTERNAL HEAT OF THE EARTH AND ITS EFFECTS.

THE facts recounted in the last chapter respecting igneous rocks have prepared us in some measure to understand how new land may be formed. While the action of water in the shape of rain, ice, rivers, and sea-waves is to wear away the surface of the land, and to carry down its waste and spread it abroad at the bottom of the ocean; we have learned that, deep in the interior of the earth, there is an antagonistic force at work, viz., heat, which softens and even renders liquid great masses of stony matter, and then forces them into and through the solid rocks above them; sometimes in such volume that they are poured forth in thick sheets over the surface. But if this were the only way in which new land is formed, it is clear that, with the exception of the alluvial plains of rivers, such as that on which we live in Bengal, the only visible rocks would be those of igneous origin, such as cover the greater part of the Bombay Presidency; and we should nowhere find sandstones, limestones and the like, full of the remains of marine animals, such as enter into the structure of the Khasi Hills, the elevated land of Western Bengal, a great part of Central India, and even the lofty peaks and mountain ranges of Tibet. The question therefore still remains to be answered,—how are old sea bottoms lifted up, so as to become part of the highlands and mountains of existing continents?

To answer this, we must begin by endeavouring to ascertain if there are any cases on record, in which land is known to have been raised bodily out of the sea: and we may at the same time conveniently extend our enquiry, and collect evidence on all changes of the land's level, including therefore those cases in which land has been bodily depressed: for if great movements of this kind take place at all, it may be expected that they will not always be in the same direction, but that they will be sometimes upwards and sometimes downwards.

There is at least one case on record in India, in which a large tract of ground has been depressed within the present century. On the 16th June in the year 1819, a very severe earthquake or shaking of the ground was felt over the greater part of India. The vibration was felt at places as far apart as Khatmandú in Nepál, Calcutta and Pondicherry, but it was of greatest violence in the Province of Kachh in Western India. The village and fort of Sindri on the eastern arm of the Indus were submerged, and a portion of the tract known as the Run was depressed, so that the sea entered an old channel of the Indus, and for some years formed a salt water lagoon where the ground had previously been under cultivation. The depression has since been in a great measure filled up by the sediment deposited from the Indus, so that the Run is now covered with water during only a part of the year. At the same time another tract in the neighbourhood of the Run was elevated into a long low mound, which received the name of the "Allah Band." Changes of this kind have been known to accompany earthquakes not infrequently, and sometimes they are more extensive and more striking than the above. The southern part of South America has been affected in this way several times within the last century. Mr. Darwin tells us that, in the Chonos Archipelago, the island of Lemus was suddenly elevated eight feet, during an earthquake in 1839; that in 1835 a rocky flat off the island of Santa Maria was, at one blow, upheaved above high-water mark, a height of more than 8 feet, and was left covered with gaping and putrifying mussel-shells still attached to the bed on which they lived; also that in 1822, the city of Valparaiso was suddenly lifted 3 feet.

But the depressions and elevations which take place during earthquakes, although more striking on account of the suddenness of the change, are really less important than those movements, which progress so slowly, that they are insensible to the inhabitants of the district affected; and are known, only by reference to rocks and similar landmarks, which in the course of many years are found to have sunk, or to have risen above the position which they formerly occupied; or by beds of recent shells, the wrecks of ships, &c., being found at considerable heights above the sea. Evidence of this kind may be met with around the coasts of India. On the southern bank of the Chilka Lake in Orissa, a bed of mud containing shells of the same kind that now live in the outlet of the lake, (where it communicates with the sea,) occurs at a height of 20 or 30 feet above the highest level of the water. This mud-bed was at one time the bottom of the lake, and must have been elevated 30 or 40 feet to its present position, since the animals lived, the shells of which it contains. At many places along the Madras coast similar beds of shells occur a few feet below the soil, sometimes several miles inland, and at levels of 10 or 20 feet above the sea. In the excavation of the coast canal that runs to Madras from the Pulicat Lake, and thence to Sadras, beds of this kind are exposed; and in the districts of South Arcot and Tanjore are many similar examples. The northern extremity of Ceylon around Jaffna, with a part of the opposite coast of Travancore, consists entirely of coral-rock, containing numerous embedded shells, all of the same kinds as are now living in the sea around the coast: and in Katiwár, beds of similar shells were met with by Mr. Theobald many feet above the sea. In all these cases an elevation of the coast has taken place, producing more or less new land; and although the people preserve no traditions of the event, it is clear that it has taken place since the sea was tenanted by the same kinds of animals that now live in it.

But it is in South America that evidence is most abundant of a great elevation of the land in quite recent times. I have already mentioned the small upheavals that have occurred during earthquakes in the present century. But these are only minor episodes in a movement that has raised the whole of Patagonia, Chile, and La Plata to heights varying up to 1300 feet. At Valparaiso, for instance, shells once living on the sea bottom, are found undecayed on the surface of the ground at this height, and at Lima, the remains of pieces of woven rushes, decayed cotton string, and heads of Indian corn have been found embedded with sea-shells at a height of 82 feet, showing that an elevation, to that extent at least, has taken place since the country has been inhabited. Mr. Darwin's observations show, that the whole of the southern part of the South American continent has thus been equably upraised, in times geologically recent. In South America he remarks, "everything has taken place on a grand scale, and all geological phenomena are still in active operation."

On a smaller scale, Europe furnishes examples of a similar kind. The northern part of Scandinavia has long been subject to a slow and imperceptible elevation. Near Uddevalla, shells adhering to the rock, as they once lived, were found by Sir Charles Lyell 100 feet above the sea; and marks cut in the rocks in 1820 at certain places north of Stockholm, were found to be 4 or 5 inches higher above the sea level, when reexamined fourteen years afterwards. From all the evidence that has been collected, Sir Charles Lyell concludes that, proceeding from the North Cape southwards to Stockholm, the rate of elevation diminishes from several feet to a few inches in a century.

All these observations relate to places on or near coast lines, but it is only in such situations that, as a rule, proofs of elevation or depression are easily obtained. The reason is, that all heights are measured from the level of the sea, and there are few countries where the heights of the interior have been known long enough and accurately enough to enable us to say whether they have undergone any change. Only in such cases as that of Patagonia and Northern Scandinavia, where both coasts can be shown to have undergone the same kind of movement on a great scale, can we safely infer that the whole mass of the land has participated in the movement.

Hitherto I have spoken chiefly of movements of elevation. But downward movements sometimes occur. They are not in general quite so easy to trace, because when land has once been covered by the sea, it is not open to examination. On the south coast of England and the opposite coast of France, there are many places, however, in which the submerged remains of former forests are exposed when the water falls very low at spring tides; and nearer home I have already noticed the occurrence of stems of Sundri trees, exposed in digging tanks to depths below the low water level of the sea; and in the case of the boring at Fort William, at 380 feet beneath the surface. The southern part of Sweden is known to be gradually sinking while the northern part is, as we have seen, rising; and from evidence drawn from the habits of the coral animal and the shape and character of coral islands such as the Maldives and the Laccadives, it is inferred, that all those parts of the ocean in which these and similar islands occur, have been very slowly subsiding, probably with intervals of rest, for many thousands of years.

What is the cause of these great movements, that slowly, in the course of ages, work such great changes in the form and elevation of the land? Of this we know very little; little more indeed than that they are in some way connected with the condition of the interior of the earth; and are probably due to the shrinking of the earth, in consequence of a gradual loss of heat. It is now time that we should turn our attention to this subject.

The warmth or *temperature* of the ground surface is almost entirely dependant on the heat of the sun, and is therefore always greater in the day time than at night. It varies as the temperature of the air varies, but to a greater degree, for when the sun has been shining upon it for some hours it becomes hotter than the air a foot or two above it, while on a clear night it becomes colder than the air. But this is true only of the *surface*. A few inches below, the difference of the day and night temperatures is very much less; and in the temperate zone, at a depth of from 3 to 5 feet, disappears; so that at this depth, the temperature is the same, day and night, at the same time of year. The difference of the summer and winter temperatures affects the ground to a much greater depth, but at 80 or 90 feet in the temperate zone this also disappears. At Paris, a very delicate *thermometer** in the cellars of the Observatory, 90½ feet below the surface, has marked the same temperature for 50 years. In Calcutta this point of constant temperature is probably much nearer the surface, but no observations have yet been made in India to determine at what depth it lies. Below the level at which the heat of the ground is no longer affected by the difference between summer and winter, the warmth increases the deeper we descend into the earth. The increase is much greater in some places than others; but on an average it is such, that it is calculated, that everywhere at a depth between 10,000 feet and 20,000 feet, the temperature is that at which water boils, or would boil if at the surface.

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* A thermometer is an instrument for measuring temperature. It consists of a glass bulb filled with mercury, having a very fine tube attached, which is also partly filled with the fluid metal. With increase of temperature the mercury expands and fills more of the tube, and contracts as the temperature falls.

That the temperature of the interior of the earth is high, is further proved by hot springs.

In the Karakpúr hills near Múngher there are several springs of hot water, gushing out of the earth or from cavities in the rocks. One of these, close to Múngher, is well-known as the Sita-Khúnd. Another well known spring of hot water is one that gushes out at Gangútri at the source of the Ganges, and many others are known in different parts of India. All these springs come from a great depth, and their heat is derived from rocks deep in the earth, through which the water has passed before coming to the surface. In volcanic countries, hot springs are very common; and they occur also among hills and mountains, where the rocks have been much disturbed at some former period, as is the case both in the Karakpúr hills and the Himálaya. They are never met with in the middle of great river plains, where the deposits formed by the river are of considerable thickness. It would be in vain therefore to search for such springs in the rice fields of Lower Bengal.

But the most striking proof of the high temperature of the earth's interior is afforded by volcanos. A volcano is the orifice or opening of a vent or channel, which communicates with the interior of the earth; and through which, heated water and steam, various gases and stony matters, frequently liquified by heat, are ejected, in some cases continually, in other cases at intervals of many years; while the intervening periods are periods of rest during which the orifice is completely or partly closed.

In India there is at the present day no active volcano. The nearest is that of Barren Island, an isolated volcano forming a small island in the Bay of Bengal, not far from the Andaman Islands. The accompanying figure is a representation of this island, reduced from one given in the XXIXth Volume of the Journal of the Asiatic Society.

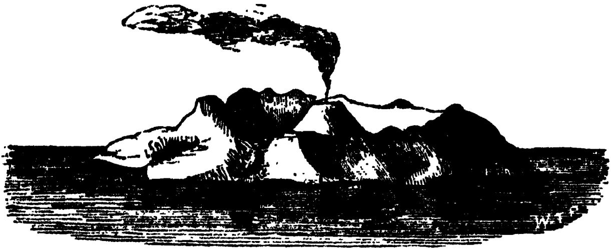

Fig. 6.—Barren Island.

It consists of a conical hill surrounded by a ring-shaped mountain; and at the summit of the former is an orifice, through which sulphurous gases are emitted, and which is termed the *crater*. Both the conical and ring-shaped hill are formed of stony matter which has been ejected from the crater during former periods of activity; for there has been no eruption of this particular volcano for the last 70 years. In 1795, Captain Blair describes the smaller central cone, as throwing out showers of red hot stones of several tons weight, and enormous volumes of smoke; and Horsburg states that, in 1803, the volcano was observed to explode every 10 minutes, projecting each time a column of black smoke perpendicularly to a considerable height; and in the night a fire of considerable size continued to burn on the east side of the mountain.

The whole island is formed of the materials thus ejected, including melted rock, termed *lava*, which has poured out from the lower part of the mountain, and is now solidified as a hard black cindery-looking mass. The whole of the cavity within the ring-shaped mountain is an old crater; and the cone within, which is nearly 1000 feet high, has been formed by the matters ejected when the activity of the volcano had much declined. Were it again to become as active as it once was, the first act of the explosion would probably be to destroy the greater part of this cone, and it might be, even a part of the outer ring, a new crater being perhaps formed in a different spot. Such has been the history of the well known volcano of Vesuvius near Naples; which, up to the year 79 of the Christian era, was regarded as extinct, and covered with cultivation, large towns being built around its foot. In that year it broke out again in a very violent eruption: a great part of the old ring was destroyed, a new cone and crater formed, and the cities Herculaneum and Pompeii were completely buried beneath the ashes ejected from the mountain. For more than 1600 years, their existence remained a mere historical tradition, but they have now been excavated, and not only have the public buildings, the theatres, baths, dwelling houses, and shops of the ancient Roman inhabitants of Pompeii been laid open to us, with their wall paintings and sculpture as fresh as they were 1700 years ago, but all the details of their domestic appliances are brought to light; and by pouring plaster of Paris into the cavities left by the bodies of the buried inhabitants, casts have been taken, which reproduce the external forms of persons who perished in a catastrophe 1700 years ago. That this city has been so completely preserved, is owing to its having been buried beneath the light volcanic ash or dust which forms a large part of the ejected matter of volcanic eruptions. Cases are on record, in which this has been poured forth in such vast quantities as completely to obscure the sky. Such was the case in the great eruption of Tumboro, a volcano in the island of Sumbawa, in 1815. It is stated that "the darkness occasioned in the daytime by the ashes of this eruption in Java, (more than 200 miles to the westward,) was so profound, that nothing equal to it was ever witnessed in the darkest night;" and some of the finest particles were transported to the islands of Amboyna and Banda, which last is 800 miles east from the site of the volcano. The cinders floating on the sea to the west of Sumatra "formed a mass 2 feet thick, and several miles in extent, through which ships with difficulty forced their way."

Volcanos rarely occur isolated. Most frequently they are arranged in a linear series, and some of these lines of volcanos are many thousand miles in length. Thus Barren Island is now the northernmost of a line of volcanos which extends the whole length of Sumatra, Java, and through the smaller islands Sumbawa, Timor, &c., up to New Guinea. Another line runs through Japan and the Philippine Islands to the same point; and a third extends to the eastward, through the Solomon Islands to the New Hebrides. In the Andes of South America, which contain some of the loftiest volcanos of the world, the arrangement is of the same character, and so also in Mexico.

Another very general character is, that most of them occur either on islands or at no great distance from the sea; and it has been thought that the percolation of water to the heated interior of the earth is one of the causes which determine eruptions. Vast quantities of steam and heated water are among the substances poured forth on such occasions, and the expansive power of highly heated steam is such as certainly might exert the enormous explosive force exhibited in volcanic eruptions.

Closely connected with volcanos are those disturbances of the ground, which I have already spoken of as *earthquakes*. Volcanic districts are especially liable to them, and great eruptions are generally preceded by earthquakes; as if those explosive forces which produce the eruption were struggling to find an outlet. But they are not restricted to the neighbourhood of active volcanos. Some of the most violent, indeed, have occurred in places where there is now no active volcano, and there are few countries in which slight shocks are not occasionally felt. There is no active volcano for instance in the neighbourhood of Kachh; and in Bengal we sometimes have slight earthquake shocks, although as I have already stated, there is no volcano nearer to us than Barren Island. Most of those that we feel in Bengal proceed from the eastward; from the Irawadi valley and the country adjacent. One which was felt in August 1858, was most severe in Ava, and another on the 10th January 1869 was extremely severe in Kachar and the hills to the northward. But below Ava there is a large extinct volcano called Puppa Doung and another, Hawshuenshan, also extinct, exists in the immediate neighbourhood of Momien. These prove that, at no distant date, (in a geological sense,) the line of volcanos, which now terminates in Barren Island, has extended far up the line of the Irawadi valley and the country adjacent to it; and the earthquakes, which proceed from this region, may be regarded as due to the same causes which were once powerful enough to produce large volcanos in the same tract.

An earthquake is a trembling of the ground, a kind of molecular wave or vibration, propagated through the solid earth; in the same way that if a long massive bar of iron be struck at one end with a heavy hammer, the disturbance is propagated through the bar to the further end. The original cause is probably an explosion deep down in the earth, just beneath the place where the earthquake is most violent. Great earthquakes are very destructive, especially to buildings; which in slight cases are cracked and thrown out of the perpendicular, and in severe cases, thrown down in ruins.

One of the most destructive earthquakes of modern times was that which occurred at Lisbon on the 1st November 1755. A sound like that of thunder was heard underground, and immediately afterwards a violent shock threw down the greater part of the city. In the course of six minutes, sixty thousand persons perished. The destruction was much increased by a gigantic wave, (the effect of the earthquake,) which rolled in from the sea; the water at first retired and laid the bar of the river dry; it then rolled in, rising fifty feet or more above its ordinary level. This earthquake was felt over an extent of the earth's surface, which Humboldt computes to be four times greater than the area of Europe, but nowhere with such violence as at Lisbon.

The phenomena, of which an account has been given in this chapter, have their origin in the interior of the earth; and the agent is heat. This heat is undoubtedly so great, that were it not for the enormous pressure of the solid rocks that form the surface, (together with that of the great mass of the sea,) everything would be in a molten state; but, on the other hand, the pressure is so enormous, that were it not for the great heat, everything would be crushed into a solid denser and heavier than copper or lead. What is the actual condition of the earth's interior, we do not well know: but it is the opinion of some of our best physicists, that as a whole, the earth is a very rigid mass; for it is computed, that were it not so, tides would be produced in the solid earth like those of the sea, and observation shows that there are no such tides.

How the interior of the earth has acquired its high temperature, is a question which we cannot well answer from actual experience. It has been shown by Fourier, (a very eminent French mathematician who lived at the beginning of the present century,) that the earth cannot have received this internal heat from the sun, for then it would be hottest at the surface; whereas we have seen that it becomes hotter as we descend towards the interior. The only answer then that we can give is, that this heat is primeval, and has existed in it ever since the earth acquired its present form. It is considered probable, that at some immeasurably distant period, long before it was tenanted by living creatures, our globe was an exceedingly hot, liquid or even gaseous mass, something like the sun on a small scale, and that through countless ages it has cooled slowly to its present state. It is cooling even now; for more heat goes away from the surface into space, than is absorbed by it from the sun; but this loss of heat is very slow; and many hundreds of thousands of years may yet elapse, before any considerable effects of the cooling become perceptible to its inhabitants. In the next chapter we shall see how this cooling results in the production of mountain chains and some of these volcanic phenomena, the elevation and sinking of the land, &c., that have been described in this chapter.

CHAPTER VI.

MOUNTAIN CHAINS.

In the last chapter I have spoken of only one class of mountains, *viz.*, those formed of volcanic rocks. We have seen that volcanos are mounds of stony materials, accumulated round an orifice communicating with the earth's interior, from which they have been ejected; and hence they have generally a conical form. Sometimes they occur in clusters like the mountains of Iceland, the Azores and Canary Islands; but more frequently in long chains, like those of Java and the Andes; and in this latter case they are frequently associated with a more or less continuous mountain range. Although mountain ranges are frequently destitute of active volcanoes, (for there is no volcano in any of the ranges that traverse India, nor is there any in the Alps or Pyrenees of Europe,) there is at other times an evident association of the kind. Even mountains, which, like the Himálaya, contain no volcanic cone, most frequently exhibit here and there masses of volcanic rock; which prove that, at some past period, they have been the seat of volcanic activity: and the existence of hot springs and the occasional occurrence of earthquakes in this mountain range, bear testimony that the power formerly so active, though subdued, is not yet departed or extinct.

Those who have seen the Himálaya, or the Western Ghats, the Garo, Khasi and Jaintia hills of Eastern Bengal, or the ridges of the Arakan Yoma which run between the Irawadi and the Bay of Bengal, will understand what is meant by a *mountain chain;* and, on a smaller scale, the Rájmahál hills, or those of Karakpúr which terminate at Munghér, will equally serve as examples. A *mountain range* or *chain* is a tract of elevated and broken ground, generally much longer than it is broad, and consisting of one or more ridges parallel to each other and to the longer axis; from which other ridges branch off more or less at right angles. Between each pair of ridges lies a valley with its stream or river; which carries off the drainage of the ridge on either side, and is continually deepening the valley in which it runs. It carries away the waste of the mountain slopes, in the form of sand and mud, to spread them abroad over the low plains beyond the mountains or to deposit them in the depths of some distant ocean.

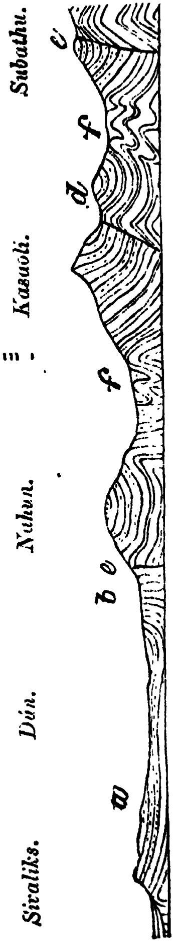

Fig. 7.—GEOLOGICAL SECTION OF A PORTION OF THE SIMLA RIDGE.

To understand how a mountain range is formed, let us examine the structure of a part of the ridge on which Simla is built; which will serve as a fair example of mountain structure in general. Supposing a section to be made through the mountains, from the outer slope of the Sivaliks to the hill of Boj above Subáthu, (like some gigantic railway cutting,) the appearance presented would be much like that shown in the accompanying figure.* The rocks would be at once recognized as those of the sedimentary class, whose mode of formation has been described in the fourth chapter. But how changed in appearance from the level layers which they once were, when spread abroad on the bottom of the sea. At *a*, where the section passes through the Sivalik hills they are only lifted up and slightly inclined; but beyond, to the right, as we advance from the Dún into the mountains, they become turned up and contorted; as if, instead of being hard massive rock, they were so many layers of cloth, or other soft, flexible substance. At *b* the once horizontal layers are vertical; at *d* and *e*, the whole mass has been broken across and dislocated; the rocks on one side of the fracture having been lifted up many thousands of feet; and at *f* they are crushed and crumpled together, as the leaves of a book might be, if placed edgewise between the boards of a powerful press. Were all these beds of sandstone and clay, (now hardened into dense rock,) spread out again, as they once were, in level layers, they would occupy probably twice the space that now intervenes between the Dún and the Boj (above Subáthu): and if we were to continue the section through the whole chain of the Himálaya for some 100 miles, and still further, across Tibet to the plains of the Gobi Desert, we should still find the same evidence of crushing and contortion. Here then is the work of a power, compared to which, the greatest earthquakes on record sink into insignificance. Since man began to record his experience of natural catastrophes, no one has ever witnessed such gigantic movements of the solid crust of the earth as here stand in evidence. Yet, in a geological sense, they are not ancient; or rather they are very recent. In these very rocks, are found the bones of elephants and other animals, all indeed extinct, but still such as we know to have lived only in the latest ages of our earth: it may be that even men have witnessed them; but if so they lived long anterior to the dawn of existing tradition.

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* Taken from Mr. H. B. Medlicott's Report, in Vol. III of the Memoirs of the Geol. Survey of India. I have taken the liberty of completing the details down to the level of the plains.

If then we desire to ascertain how these changes came about, we must have recourse to some source of information other than those of history. We must endeavour to find out what power there is in nature competent to produce them; and having found such a power, we must examine whether the effects we have observed are such as might be expected from what we know of its action.

There is such a power in the gravitation of the earth: that is to say, in the force which draws every part of the earth towards its own centre; if we suppose that, by any means, the interior of the earth has contracted, and so ceased to afford a complete support to the solid layer that forms the external shell. To render this idea clear, let us suppose that the accompanying figure represents a section of the earth, cut in half, and

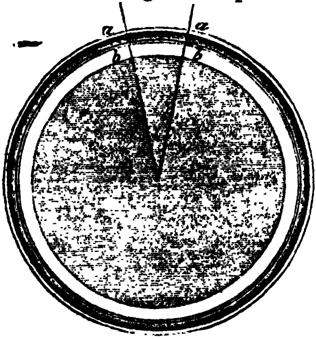

Fig. 8.

exposing *a a*, the external shell, and *b b* all that lies within it. Next let us suppose that, from some cause, which has yet to be assigned, the interior portion *b b* shrinks so as only to occupy the shaded space, while the shell is affected by no such shrinking, or is at all events less shrunken. The shell will then be left partially without support; and under the influence of gravitation, it must somehow adapt itself to the diminished size of the core. It can do so only by acquiring a diminished surface, which will be effected somewhat in the manner represented in Figs. 9 and 10, which represent a small portion of the shell and nucleus. It is evident from the figures, that the portion of the shell *a a* must somehow squeeze itself into the narrower space at *á á*; and to do so, either it must undergo fracture and some portion of the fractured mass must protrude beyond the rest, as shown in Fig. 9; or else, if flexible, it may be crumpled up as represented in Fig. 10. Most probably the adaptation will be effected partly by fracture and dislocation and partly by contortion. Now let us turn back to Fig. 7. Here we have fractures and dislocations of the same kind as in Fig. 9—and, in the intervals, the bedded rocks are contorted just as we should expect from their having to adapt themselves to a diminished space. Such is the general character of mountain ranges; and we must, therefore, regard them as portions of the earth's surface, which have been broken and crumpled up, in a manner such as would follow from the shrinking or contraction of the interior. Thus we may have a portion of

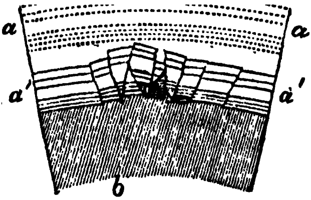

Fig. 9.

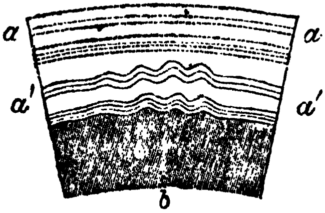

Fig. 10.

the surface, that has for ages been level, thrown up into a series of ridges, producing ranges of mountains as lofty as the Himálaya and the Andes. Another effect of this contortion and squeezing is a great change in the character of the rocks, *viz.*, that which was described in the fourth chapter as *metamorphism*. The rocks have been so heated by the pressure that they have become softened and partially fused; and when cooled again, very hard, compact and crystalline. In the Himálaya it is only on the flanks of the chain, *viz.*, in the neighbourhood of the Gangetic plains on the south, and in the valleys of the Spiti and the Sutlej on the north, that the rocks retain much of their original characters *distinctly* as water-formed deposits. All the great intervening mass, including the loftiest snow-covered peaks, consists of metamorphosed crystalline rocks, and such is also the case in the Alps, the Andes and other great mountain chains. Here and there, masses of granite and other rocks of the same class, breaking through the fractured and contorted gneiss, show that, in some cases, the heat aided by water has been sufficient to liquify the rock; and elsewhere, intruded rocks of the volcanic class bear witness to a similar action.

Paradoxical as it may seem, the structure of mountains shows us then, that they have been produced by crushing; by the necessity that some portion of the earth's surface shall accommodate itself within narrower limits; in consequence of which, that which is in excess, is squeezed up above the general level. This may form one or many parallel ridges, according to the magnitude of the crushing and to the extent of the country affected. In the case of the Himálaya there are many parallel ridges;* and the whole of them may be regarded as forming only the southern border of a much more extensive elevation, the table-land of Tibet. It must not be supposed that the great movements, by which such mountain masses are produced, take place all at once. In the case of the Himálaya, for instance, it can be proved that the same kind of movement has been repeated again and again, at long intervals; so that sedimentary formations which were formed of the waste of the primitive ranges, have been themselves lifted up

* See Chapter XI.

and contorted during later movements. In the next and following chapters, we shall have more to say about the wearing down to which they are and have been subjected; and in consequence of which, they and all existing mountains present an appearance very different from that of the broken masses which would result immediately from such a process as I have described.

We must now turn our attention to the cause of the earth's shrinking, which I have hitherto only *assumed* as the ulterior cause of the formation of mountains; and we must bear in mind, that it is not the mere fact of the shrinking, that we have to account for; but that to produce the effects described, this must take place unequally, and the interior must contract more than the surface. In the description, and Figs 8, 9 and 10 on a previous page, I have supposed, for the sake of clearness, that the external shell is quite distinct from the inner mass, and that the latter contracts as a whole, so as to separate itself from the shell, which remains uncontracted; lastly, that the breaking up and falling in of the shell takes place subsequently as a distinct and independent movement. This of course is really not the case. The shell could not remain for an instant unsupported as it is represented in the figure, and must accommodate itself to the contracted nucleus, as fast as the latter contracts. But the final result will be the same.

The only cause we know of, competent to produce such an unequal shrinking, is that mentioned at the end of the last chapter, *viz.*, the loss of heat. A very familiar illustration of the shrinking of a cooling body may be seen in any blacksmith's shop. When a blacksmith makes an iron tire for the wheel of a bullock cart, he makes it a little smaller than the wooden wheel to which it is to be fitted. He then covers it with burning cow-dung, and when thoroughly hot puts it on the wheel. The heat expands it, and it now fits easily. Finally he cools it by throwing cold water upon it, causing it at the same time to contract to its former size; and, in so doing, it closes tightly on the circumference of the wheel and squeezes all its parts firmly together. With very few exceptions, all substances expand in like manner when they are heated, and contract when cooled. If, therefore, it can be shown that the interior of the earth is cooling, while the surface remains always of the same temperature, or nearly so, we shall have just the state of things required to produce those disturbances of the surface that have been described in this and the previous chapters.

Now we know from experience, that whenever two parts of one and the same body are unequally hot, heat travels from the hotter to the colder part. In some cases this flow of heat is rapid; in others it proceeds very slowly. If we take a bar of iron, or still better one of copper, and put one end in the fire, before very long the heat will have travelled along the bar, so that the end furthest from the fire will become too hot to hold. If however a number of bricks be built up with mortar or clay in a furnace wall and a fire be made inside, it must burn a long time and very fiercely before the bricks become too hot on the outside to be touched; and this will be due to two causes: one is that heat travels through a brick much less quickly than through a metal; and the other, that the outside being exposed to the air, the heat is thrown off from it almost as fast as it reaches it; so that the outside remains but little warmer than the air.

But if one of the bricks be removed from the outside of such a wall, the interior will be found quite hot; showing that the heat has penetrated it. Now, for the furnace wall, let us substitute the highly heated interior and cool shell of our earth. The heat of the former *must* travel towards the surface, and on reaching it *must* be thrown off into free space. The surface always remains therefore at much the same temperature. All the heat that it receives from below is at once lost, and were it not for that of the sun which it receives during the day time, it would be so intensely cold, that no living thing could exist upon it. But it is maintained at a moderate degree of warmth by the sun, and as this varies but little from year to year, or as far as we know, from century to century, it undergoes but little change on the whole, while the interior of the earth is always losing heat, or cooling.

The train of observation and reasoning which we have followed in this discussion of the causes that produce mountains, is a good example of that followed generally in explaining the phenomena of nature. Let us briefly sum up its leading points. First of all, we learn by examining the structure of mountain chains, that they are composed of rocks, a great part of which have at one time formed level layers at the bottom of some ocean; that in mountains, these are contorted and broken in a manner that proves them to have been squeezed into a space less than that which they must once have occupied. And reason tells us that, as the surface of a small ball is less than that of a large ball, such an effect would follow, if the outer layer of a larger ball were forced down upon the surface of one which is smaller. In the case of our earth, if the interior were to shrink, while the outer shell were not so affected, gravitation would constantly force it to adapt itself to the diminished size of the former. And finally our knowledge of the manner in which heat is propagated from the heated end of a bar to the cool end, and therefore from the heated interior to the cool surface of our earth, whence it is radiated away into space—combined with the further fact, that with rare exceptions, all cooling bodies shrink as they cool,—assures us that the interior of the earth must be contracting, and that the outermost part of the shell does not so contract, except under the influence of gravity.

From all this it follows that our earth must once have been larger than it now is, and that it will some day be smaller. Undoubtedly it is so; but the change is a very slow one. The mountain ranges on its surface are the cracks and ridges that have been produced by its contraction; and since there are other causes at work, which we have yet to study more in detail, which are always wearing down all irregularities, we might conclude that the most ancient mountains must long ago have been worn down to low hills, and that the loftiest mountains are some of the most recent. Geology assures us that this is so.

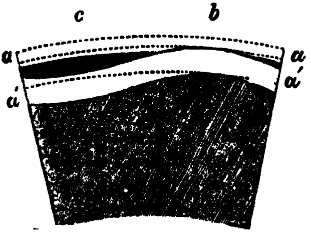

Fig. 11.

The causes that we have found to explain the formation of mountains, will also explain those gradual upheavals and depressions of the surface, described in the last chapter. Let *a a* represent a portion of the surface evenly covered with water; and, in consequence of the contraction of the earth's interior, let it be forced to accommodate itself within the smaller space *á á*. If the difference be not very great, this portion of the superficial crust, instead of being contorted or broken up, may be simply bent into the double curve represented in the figure. Dry land, a portion of a new continent for example, will emerge at *b;* and at *c* a deeper depression will be formed, in which all the water will accumulate. Now it has long been observed that when any great tract of land is being upraised, there is, as a rule, at no great distance, another tract undergoing depression. While the north of Scandinavia is rising, the south is being depressed; and Mr. Darwin has shown reasons for inferring that, in the Pacific Ocean, the line of volcanic islands mentioned in the last chapter, (and consisting of New Britain, the Solomon Islands and the New Hebrides,) are undergoing occasional slow elevation; while, on either side, the existence of coral islands of the kind termed *atols* and *barrier reefs*, gives evidence that gradual depression is in progress. On the north are the Caroline Islands, the Marshall Islands, &c., and on the south the Lonisiade, New Caledonia, and the great barrier reef off the north-east coast of Australia. Still nearer home, we have another example. The east coast of Arabia has been raised above the sea, at a period geologically speaking recent; while the existence of the Laccadives and Maldives and other groups of coral islands to the south of these, show that the North Indian Ocean has become of greater depth than formerly.

Before we quit the subjects treated of in the last two chapters, it remains to show how the contraction of the earth and the consequent distortion of its crust may give rise to volcanic eruptions, and produce that metamorphism of the central parts of great mountain chains which we have seen to be their general characteristic.

It has long been known to physicists, that if any substance be placed under great pressure, it becomes heated. Dr. Tyndall showed some years ago, that ice, for instance, can be melted by squeezing it under a powerful press; and the fact that pieces of metal are heated under the like circumstances is well known to all persons who have to deal with powerful machinery. The crushing force by which mountain masses have been elevated, must therefore have produced heat proportional to the intensity of the pressure, and Mr. Mallet has shown, by experiments on different kinds of stones, that this has been sufficient to metamorphose the rocks, (already perhaps at a high temperature owing to their depth below the surface,) and even to melt them in those central parts of the chain, where, as a rule, the lowest rocks have been thrust up to the surface. In this way, probably, may be explained the fact noticed above, that the central parts of great mountain chains are generally formed of metamorphic rocks.

I cannot better sum up the teachings, and point the moral of these two chapters, than in the words of Sir John Herschell. "The land," he says, "is maintained in its elevated position by internal force, locally exerted, and varying its locality from age to age, ... Whatever be the nature and ultimate origin of that force, it is manifested to us from time to time in the volcano and the earthquake, which thus we learn to regard as very far from purely destructive arrangements in the great scheme of nature; since without the agency of which they are part and parcel, there would by this time have been no dry land whatever. The fact that all our present continents consist of beds or strata, which have resulted from the destruction of former ones, and the distribution of their materials at the bottom of the sea; and on granitic masses, forcibly thrust up through those strata, disturbing and dislocating them; leads direct to the conclusion that, had the primeval world been constructed as it now exists, time enough has elapsed and force enough, directed to that end, been in activity, to have long ago destroyed every vestige of land, but for the reproductive efficiency of those internal forces bringing up continually new lands to replace the old."

CHAPTER VII.

ICE AND SNOW.

No single mountain range now presents to our eyes the aspect it must have had, when newly upheaved, a contorted and fractured mass, under the enormous pressure of the contracting crust of the earth. Lofty as are still the snow-capped peaks—Mount Everest, Kanchinjinga, and Doulagiri—they have all been wasted under the eroding tooth of frost; and began to contribute their quota to the soil of the Bengal plains and the sediment of the ocean, from the very first moment of their upheaval. Destruction and renovation are the law of the insensient rocks, not less than of our own bodies and other living things. I have briefly sketched out the latter; let us now turn our attention to the former process.

The agents by which mountains and continents are planed down and destroyed, are water and a gas; water in its several forms of ice or frost, springs, rivers, and the ocean; and a gas which exists in the atmosphere and is called in chemical language *Carbon dioxide*, and when dissolved in water *Carbonic acid.* Of these, water is by far the most important and the most varied in its action, and it is only in the presence of water, and when dissolved in it as Carbonic acid, that the latter takes part in the work of destruction. The vehicle of both is the atmosphere.

We have seen in the second chapter, how water vapour is taken up by the winds from the surface of seas, lakes and rivers, and from every humid surface on the land; and is then precipitated by cooling in the several forms of cloud, snow, rain, hail, dew and hoar frost. We have seen too, that much of this precipitated water is gradually collected in rivers and so brought back to the sea. We have now to follow it through its various transformations and channels, in the interval; noticing the work it does by the way, in modelling the surface, in nourishing the verdure that clothes it, and in rendering it habitable and lovely.

On the higher mountain summits, where the temperature of the air is always at or below the freezing point, all the vapour that is condensed from the atmosphere falls in the form of snow. Since this is a solid, it cannot flow off like rain; it lies where it falls or is drifted by the wind, and accumulates in vast masses in the hollows of the mountain flanks, forming what is termed by Swiss mountaineers, the *névé*. Under the rays of the sun, the surface is sometimes melted in the day time; and sinking into the mass beneath, is again frozen; so that, in the course of time, the lower parts, pressed upon by the superincumbent weight of the later snow-falls, become compacted into ice. Lying, as it does, on the steep slopes of the mountains, the *névé* gravitates gradually downwards, and collecting in the loftier parts of the valleys, eventually forms a river of solid ice termed a *glacier*. All the higher valleys of the Himálaya and the Alps are occupied by such glaciers, many hundreds of feet in thickness, and sometimes many miles in length. One that descends from the Karakoram range separating Tibet from the plains of Yárkand, is not less than 36 miles long. The rate at which a glacier moves varies with the slope; being most rapid when the slope is steepest, and slower on a gentle incline. The central parts of the mass move more rapidly than the sides and bottom, which are retarded by friction against the rocks. In all these respects it moves exactly like a river, adapting itself to the windings and irregularities of its valley by constant fracturing and refreezing. But the motion is necessarily slow; so much so indeed, that it is only to be detected by observing from time to time the position of objects, such as staves fixed in the ice, or the large masses of rock which are frequently carried down resting on the surface. In this way it has been found by the accurate measurements of Dr. Tyndall that the rate of glacier motion varies from 5 to 36 inches in a day, on the Mer de Glace, one of the largest glaciers of Switzerland.

Though the summits of those lofty mountains which give birth to glaciers are in great part covered with *névé*, they are not quite concealed. Here and there a mass of splintered rock raises itself bare of the white coverlet, and the greater part of the snow that from time to time falls upon it is soon melted beneath the rays of the sun. Some of the water so formed penetrates the warmed rock; and in the night time or in the winter, when the sun's heat is less powerful, it freezes in the minute crevices which have allowed it entrance. Now ice occupies more space than the water which it yields when melted; and in freezing, water expands with enormous force. In some experiments made by Major Williams in Canada, bomb-shells filled with water and then tightly plugged and exposed to an atmosphere much colder than that at which water freezes, either had the plug blown out to a great distance or were rent in pieces by the expansive force of the freezing water. In like manner, the rocks exposed at great altitudes become cracked and splintered by the frost; and from time to time, masses varying in size from a mere flake up to boulders many times larger than a house, are detached and fall on the surface of the moving glacier. Thus ice-borne, they are carried down to lower levels; and eventually, are either lodged on some projecting crag by the way, or deposited on the mound of loose rocks that is always formed at the extremity and sides of the melting glacier: such mounds are termed *moraines*. They are met with in the Alps and the Himálaya at levels far below those to which glaciers now extend; and, in conjunction with other indications of glacier work, prove that, in former times, the glaciers in both these mountain ranges far exceeded the dimensions of those that still exist. In Sikkim, such accumulations of ice-borne blocks are found at about 6,000 feet above the sea; and in the Kangra valley, in the North-Western Himálaya, down to 3,000 feet above the sea-level. The glaciers of these mountains do not now reach much below 10,000 feet.

Glaciers exert a great cutting power. The exposed rocks over which they have passed (however hard) are found to have been ground down to a polished and flattened surface, frequently scored and grooved by the friction of still harder pebbles, which, firmly frozen in the ice, have been forced onwards with the moving mass. Such polished surfaces are termed *roches montounées*. Many of the Himálayan and Alpine valleys have thus been excavated in a great measure by the friction of ancient glaciers: the waste of the rocks, in the form of fine sand and mud, is carried away by the stream to which every glacier gives birth. The great rivers of the Himálaya, and all their affluents that originate in the snowy range, take their rise from glaciers; the Ganges for instance in that of Gangútri, the Jamna in that of Jamnotri, and the Tísta and its tributaries in the numerous glaciers that seam the flanks of Kanchinjinga, Chomiomo and Donkia.

It is evident that glaciers can be formed only in those regions, where more snow falls than the summer sun is able to melt; so that much of that which falls during one winter season lasts, till added to and covered up by that of the succeeding winter. On the southern slopes of the Himálaya, this is the case only at elevations above 16,000 feet. At lower elevations, all that falls is melted during the summer time, if not before, and goes to swell the rivers which drain the lower valleys. The line, above which snow lies throughout the year, is called the *snow-line.* On the northern slopes of the Himálaya it is at a greater height than on the south, *viz.*; about 20,000 feet. This is because, although colder than the latter, the northern slopes and the mountains north of the great snowy range receive much less snow. All the vapour that yields it is brought by southerly winds from the Bay of Bengal, and, (in the North-Western Himálaya,) from the Arabian sea; and by far the greater part of this vapour is condensed on the southern slopes of the mountains, especially the towering peaks of the great range. On reaching Tibet, the winds therefore are comparatively dry; and their dryness increases the further they penetrate towards Central Asia. Thus is explained the extreme aridity of Tibet and Chinese Tartary.

In other countries, the snow line descends the lower, the higher the latitude, or the greater the distance from the tropics. In the Alps it is found at 8,500 feet; in the Altai of Central Asia at 7,000 feet; in the mountains of Norway (the Dovre Fjeld) at 4,000 feet; and further north it descends to 2,800 feet on the western face of Scandinavia, which is exposed to the moist winds from the Atlantic. Nearly 4,000 square miles of the mountain area of this country are above the limits of perpetual snow. Lastly, Spitzbergen, within the Arctic circle, is covered with perpetual snow and ice down to the sea level.

In this last named region, the excess of the accumulated snow is carried off by glaciers just as in the Himálaya, but they form no moraines. In this cold climate, the glaciers flow down to the sea; and are pushed out into a depth of water, such, that the whole mass eventually breaks up and floats away. Ice is lighter than water, and when floating in salt water about one-ninth projects above its surface. The gigantic masses which detach themselves from these Arctic glaciers are thus carried away by the marine currents which bring the cold water of the polar regions towards the tropical zone; on the coasts of Newfoundland, the current that issues from Baffin's Bay is frequently laden with such floating islands of ice, gradually melting in the warmer air as they proceed on their slow journey, and hence assuming the most fantastic forms. They are termed *icebergs*. Splinters and blocks of rock, which, in common with the glaciers of warmer latitudes, these Arctic ice-streams carry down, and the mud and sand which, by friction, they have abraded from their rocky beds, are borne away on the floating iceberg, and as the ice gradually melts, are deposited at the bottom of the sea.

The midland counties of England, the eastern part of Ireland, and the plains of Northern Germany and Russia, are in many parts covered by a considerable thickness of clay, containing large blocks of stone termed *boulders*, and hence termed the *Boulder Clay*. The origin of this clay was at one time a great puzzle to Geologists; the more so, that it was observed that the contained boulders were unlike any rock that occurred in the neighbourhood; and appeared to have come from mountains many miles distant. In England they seemed to have been derived from the mountains of Cumberland and the Highlands; in Germany and Russia from the more distant mountains of Scandinavia; yet they are of such size that it is manifest no ordinary power could have transported them. At length it was observed that all these mountains, down to very low levels, bore indications of former glacier action; the moraines, *roches montonnées* and grooved surfaces, exactly like those so generally observed on the Alps. Here then was the solution of the difficulty. The boulder clay is distinctly a marine formation; for in some places, though rarely, it contains marine shells. When it was being formed, all the lowlands of Northern Europe (and we may add Asia also) were covered by the sea; and icebergs, drifting from the mountains which still remained above water, carried down rock masses and mud, like the modern icebergs of Baffin's Bay; strewing them, as they melted, over the sea bottom. The period during which this took place is termed the Glacial Period, and immediately preceded the existing state of things.

Strange as it must seem, and indeed inexplicable with our present knowledge, it would appear at least probable, that at a very distant period of the earth's history, something of the same kind has taken place in tropical India. At the very bottom of that great series of sedimentary rocks, which contains the coal beds of Raniganj, Chutia Nagpúr and Central India, there is a bed of rock boulders embedded in fine mud, strangely resembling the boulder clay of the British Isles. This resemblance was noticed by Mr. W. T. Blanford as long ago as 1856, and he ventured then to speculate on the possibility of the deposit having been formed by the agency of ice. Only last year, (1872) a boulder was exhumed from this bed by Dr. T. Oldham, flattened and marked with grooves and scratches exactly like those brought down by modern glaciers. This remarkable block is now in the Government Geological Museum of Calcutta, and is certainly not the least interesting object in that magnificent collection.

I have hitherto spoken only of those perennial accumulations of ice and snow, that are to be met with on lofty mountains and on the land of the Polar Regions. But in all countries where the winter temperature remains for many days or weeks below the freezing point, snow and ice accumulate; and sometimes large rivers and lakes are frozen over to such a thickness, that they may be traversed by men and vehicles as if they were dry land. The pure transparent ice, many shiploads of which are brought annually to India, is collected from the surface of the American lakes, which are frozen to the depth of several feet every winter.

In Canada, Northern Europe, and Northern Asia, the landscape, for many weeks and even months of the winter season, presents the aspect of a vast expanse of snow: the trees, bare of foliage, with the exception of the dark pine forests, are laden on every branch and twig with a snowy burden; and the pines, whose needle-like leaves hold it in larger masses, bend beneath the weight of their pure white canopy. The treeless steppes of Asiatic Russia become a howling wilderness of snow; and when storms arise, travellers are sometimes overwhelmed and buried in the drifts. But in fine weather, even when thus covered, they are easily traversed. The snow, when beaten hard and frozen, offers a smooth surface; over which vehicles, called sleighs, running (not on wheels but) on wooden bars shod with iron, are propelled with a speed and ease unattainable on the best metalled road. The rivers, bound fast with a covering of ice, beneath which a dark silent stream carries down the yet unfrozen waters, offer a natural roadway, and wrapped in furs to protect him against the bitter cold, the traveller speeds on from stage to stage; where double windows and the never-extinguished stove keep up a pleasing warmth, and ensure a genial resting place in the heart of the wintry waste.

In the spring, with a rising temperature, the snows melt; the rivers, freed from their icy bonds, become gorged and swollen with the accummulated drainage, thus suddenly set free; and overtopping the banks of their summer channels, submerge the surrounding flats. In the sub-arctic and the colder parts of the temperate zone, the spring is therefore the season of floods; and in some degree such is the case with all rivers and streams that are fed by winter snows. The Indus, which derives its waters almost exclusively from the mountains, and chiefly from their melting snows, is an Indian example of such a river.*

In the Arctic Regions, not only is the land covered with ice and snow, but the sea itself, is sometimes frozen. Salt water, however, requires greater cold than fresh water to freeze it; and when it freezes, the ice that is formed is free from salt; the salt being, so to speak, squeezed out in the act of freezing.

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* See Chapter IX.

In all cases in which the sea or deep lakes and rivers are frozen, the ice is formed only on the surface; and with the exception of icebergs, which are of foreign origin, it is rarely very many feet in thickness. In the case of fresh water lakes, this is owing to a peculiar property of water. Pure water, on the point of freezing, is lighter than that which a little higher in temperature; and when therefore it has cooled down to this latter degree, the very cold water floats: and since heat passes through water very slowly, that which is below cools no further until the upper layer is frozen. As a consequence, the greater part of the water below the ice sheet that forms on the surface of a lake, remains somewhat warmer than the latter, and the ice sheet first formed thickens but slowly. In rivers this is not the case. The water being in motion has almost the same temperature as the ice formed from it. Moreover ice-cold water in freezing has to part with a large amount of heat, in the mere act of freezing; and this can only escape upwards through the ice already formed. Sea water again behaves in a different manner. As already mentioned, it requires a greater degree of cold to freeze it at all than fresh water, and the ice formed by it is relatively much lighter. It floats therefore, and as in the case of rivers and lakes, by the opposition that it offers to the passage of heat, it checks further freezing. Moreover, in all these cases, snow falling on the surface of ice lies unmelted, and offers even greater resistance to the passage of heat than the ice itself. In the same way the snow that falls on a land surface, covered with vegetation, protects the plants from the intense cold of the air, while a certain amount of heat reaches them through the solid earth from below. Thus plants which would be killed by frost, may be protected and preserved through a severe winter, by a thick covering of snow; and when it melts under the rays of the spring sun, they are ready to put forth their young leaves and to open out with renewed verdure.

From what has been stated above, my readers will understand, that however little we experience of their effects in India, ice and snow play a very important part in the economy of the world. On high mountains, even in the tropics, and on the low hills of the Polar Regions, ice and frost help in the work of wearing away the rocks: and in the form of glaciers and icebergs they carry down to lower and even to the sea bottom, the waste of the land-surface. Snow becomes destructive only when it becomes compacted into ice; or when, accumulating in vast drifts, it buries men and animals, who may be overtaken by the wintry storm in some unprotected waste. At other times, and more frequently, it subserves a useful and beneficial purpose, in covering and protecting vegetation from destruction by cold; and in affording a smooth surface, over which men and vehicles can travel almost with more facility than on an ordinary road.

CHAPTER VIII.

THE HISTORY OF A RIVER.

In the Introductory Chapter we learned, from a simple observation, that rivers derive their supply of water from the rain which falls on the surface of the land; and from the descriptive survey of the phenomena of snow and glaciers in the foregoing chapter, we have further learned, that an additional source of supply is the snow which falls on the summits of high mountains and on the plains of cold countries; and which, after remaining for a longer or shorter period in the solid form, is melted under the rays of the sun, or by the warm winds that set in with the returning spring. We must now enter somewhat more into the details of this subject, noting the different modes, direct and indirect, by which the waters thus provided are gradually collected in the channels which carry them to the sea; and also the work performed by rivers in excavating those channels, and in wearing down and shaping the general surface of the land.

For our first example, we will take the case of a river, such as the Mahánadi; (any other large river of the peninsula would do as well); a river, no feeder of which comes from a cold and snowy region; and which is, therefore, supplied solely by rain and the waters which issue from the earth in the form of springs. Take any good map of the country; (of preference one of those skeleton maps issued by the Surveyor General's Office in Calcutta; on which, being unencumbered by the names of places, the course of the rivers can be the more clearly seen); and observe the ramifications of this river and its tributaries. The general arrangement, as laid down in the map, reminds us somewhat of a tree or shrub, stripped of its leaves, and with the roots partly drawn out of the ground. Only at one part of its course, and that for a short distance, are all its waters contained in a single channel, which we may take to represent the trunk of the tree. This is above the town of Katak, where the river issues from the hill country. Above this, the main stream may be traced far up into the country, but becoming less and less the further we follow it inland. On both sides, it receives numerous tributaries from the country around; and if any one of these, the Til for instance, be followed up in like manner, we see that, like the main stream, it is continually receiving minor subsidiary branches; the whole being not unlike the twigs and smaller branches on the bough of a tree. Observe too, that when once they have united to form one stream or river, they do not again separate; but continue as a single stream, until the contents of the whole are collected in the main river, some distance above the point at which we commenced our survey. Now let us trace it downwards. At the point where Katak is built, it divides into two main branches, and each of these in its turn gives off others; the main channels becoming smaller and smaller as they approach the sea. It is something like a reversal of the former picture. *Something*, but not *quite:* for the subordinate channels, into which the main stream branches out, do not in all cases preserve an independent course. Many of them after a time reunite, so that the whole system may be compared rather to the meshes of a net than the ramifications of a tree; and the channels that finally reach the sea, though numerous, are not so numerous as they are a little way inland.

We thus recognise a marked distinction between the upper and lower portions of the river. In the one, all the streams converge or run together; and the waters from all parts of the country are collected step by step and united in one main channel. In the other, the channels diverge or rather reticulate, the waters being distributed between them: and when the river is unusually full, part of the water may even leave these channels and spread far and wide over the country. These two tracts are therefore distinguished as the collecting ground or *catchment basin* and the *alluvial* tract or *delta* of the river. The first is almost always much the larger.

These differences of the river's character depend on, and at the same time affect, the form of the land surface. Above

Katak the country is either very hilly, or where, as in Chhatisgarh, hills are absent, gently undulating,—never absolutely flat; and every river flows at the bottom of a long depression termed its valley. Among hills, this valley is generally very narrow, and bounded by steep, sometimes rocky sides. Such is the case for instance at Neuraj, a few miles above Katak. At other places, the hills recede on either side and the land surface slopes gently down to the river channel; but excepting perhaps a narrow strip of flat meadow land, along one or both banks, which may be covered by the river in high floods, the whole surface is permanently above the flood level. All the rain that falls on the country, beyond that which is absorbed by the ground, or evaporated by the winds, runs down into the nearest streamlet, and contributes its quota to the volume of the river.

The river is its own engineer. The channelled depression, in which each stream flows, is the work of its own waters; and the engineer who cuts his canal with gently sloping banks in the soft soil of alluvial land and with steep walls through a hard rocky barrier, does but imitate unconsciously the example set before him by nature. But while the former works with foresight and intelligence, selecting that course which appears to him *on the whole* the easiest, and to require the least expenditure of labour, sometimes cutting through a hard stubborn barrier in his path with a view to shorten the distance, and to attain some advantage on the further side; the river, acting under the influence of gravity alone,* can only take that course which is *for the moment* the easiest,—that by which it immediately reaches a lower level; and sometimes it makes a long detour around some small obstacle, a hillock or low ridge for instance, which it cannot surmount, because an outlet exists at a distance at some lower level, through which the waters must escape. Hence it follows that rivers always follow a more or less circuitous course. Of this, the Bárak river in Kachár offers a striking example on a small scale, and on a larger scale the Indus and Bráhmaputra.

* See Introduction, p. 5.

The drainage basin of every river is bounded by a line termed the *watershed*,* or *water-parting*, which separates it from the adjoining river basins. This is frequently the highest line of a range of hills or mountains; but not always. Sometimes it is merely the most elevated part of a great plain, such as that which separates the drainage of the Jumna from that of the Satlej to the west of Delhi; but this is the exception rather than the rule. As an example we will trace out the watershed of the Mahánadi. Starting from a point on its north bank opposite the town of Katak, the line dividing the drainage of our river from that of the Bráhmani runs in a westerly direction, through the hilly Mehals of Átgarh, Ongol and Radakol. Hence it strikes northwards through a country of much the same character, till it reaches the high plateau of Chutía Nágpúr; separating the Ib, a large tributary of the Mahánadi, from the Bráhmani. Both these streams take their rise in this plateau. From this point, we follow it to the west, along the crest or highest *continuous* line of the plateau, to the north of which the drainage runs into the Són river. After descending to a lower level at the termination of this plateau in Sirgúja, the watershed makes a considerable detour to the north around the sources of the Hasto in the plain of South Riwa; and then, returning to the south, it ascends the great hill mass of Amarkantak, where these great river basins meet. These are the basins of the Són flowing into the Ganges, the Nerbudda (Narmada) into the Gulf of Kambayat, and the Mahánadi. Hence the watershed strikes southwards along the Mandla hills, the western slopes of which drain either into the Nerbudda, or the Wáinganga, a feeder of the Godávari; then, crossing the plain to the south-east, which lies between Nágpúr and Chhatisgarh, it enters the wild rugged hill country on the borders of Bastár, in which the main stream of the Mahánadi takes its rise: and finally, running to south-east through the hills drained by the Tíl river, the largest tributary of the Mahánadi, it turns to north-east through the hills that separate the drainage of the Tíl from that of the smaller streams of the east coast; and then again to east, following a line parallel to the main river, back to our starting point at Katak.

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* The word is usually thus written, but the last syllable is derived from the German word *scheiden*, to divide or part, and by Sir John Herschell the word is spelt *waterscheid*.

The country comprised in this long circuit is 45,000 square miles in extent. At least three-fourths of this is covered with rugged hills, for the most part rocky or clothed with forest; and the only cultivated tract of large extent is the fertile plain of Chhatisgarh. These characters of the basin, together with its form, which is round and compact with a narrow neck, determine certain peculiarities in the river, especially its liability to become flooded: but before noticing these, we must say something of the rainfall by which it is fed.

Most of the rain, that falls on the Mahánadi basin, is brought by westerly winds from the Arabian Sea; and these winds prevail from June to September. In the hot weather months, a few showers come from the Bay of Bengal; and in October, at the close of the south-west monsoon, rain from the same quarter sometimes extends far up into the country. But the heaviest rain is that which falls during the south-west monsoon; brought, as I have said, by westerly winds. If all the rain that falls during a year, over the whole basin, could be collected, without loss of any, on a perfectly level surface 45,000 square miles in extent, it would cover it with a sheet of water about 4 feet, or perhaps 50 inches deep. This fact is usually expressed by saying, that the average annual rainfall of this river basin is 50 inches. All this water, however, is not carried away by the river. A part of it, we scarcely know how much, is re-evaporated, and passes back into the air. Another part, after soaking into the ground, is absorbed by the roots of trees and the smaller vegetation which covers the surface; and much of this also, evaporating from the surface of the leaves and herbage, passes back into the air: the remainder is converted into wood and leaves. Perhaps about half of the whole rainfall is disposed of by evaporation and in contributing to the growth of the vegetation. The residue reaches the river in two ways. When the rain is heavy and the ground has already been soaked by previous rain, the larger part runs at once into the nearest streamlet, carrying with it earth and sand, dead leaves and other light bodies lying on the ground. This it is that produces *freshets* and *floods*, filling the channels, and when the rain is very heavy and extensive, even causing the streams to overflow their banks; in which case the latter are cut away, and whole trees and sometimes houses and living animals* are swept away by the swollen waters. The Mahánadi is notorious for the magnitude and destructive character of its floods, and this is due to the generally hilly and rocky character of the country drained by it: in consequence of which, when heavy rain falls over a large part of the basin, the water rapidly runs off the steep hill slopes, and is carried into the main channel. In a great flood which occurred in July 1855† and lasted for seven days, the quantity of water discharged by the river was, in round numbers, 761,770 millions of cubic feet, or rather more than five cubic miles. If this quantity of water were distributed equally over the 45,000 square miles of the basin, it would cover it to a depth of $6\frac{8}{10}$ inches. But the actual rainfall must have been greater than this. Captain Harris estimates that a great rain storm in which 9 inches of rain should fall, (in addition apparently to the ordinary rainfall of the season,) would suffice to produce this flood, but it seems probably that a smaller quantity would be ample.

Great floods, such as this, occur only once in three or four years: but all through the usual rainy season, a very large body of water flows down the Mahánadi and all rivers similarly situated. During the dry months of the year, especially from February to May, the river is low; but even then more than five hundred millions of cubic feet of water, on an average, pass down every day. Whence comes this great volume of water? There is but little rain, even in the hills, in these months. An occasional thunderstorm is the only contribution; and at Sambhalpúr, the quantity thus received does not amount, on an average, to 1 inch of rain in a month; which, falling on dry ground, must be in great part absorbed. It is in this absorption of rainwater by the ground that we

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In a great flood in July 1872, large numbers ot cattle, human bodies and even elephants were carried down past Katak.

† These data, together with the area of the basin above given, are taken from a paper by Captain Harris in Vol. XXX of the Asiatic Society's Journal.

have the explanation of this constant supply. However dry the surface of the ground may be, there is always water at a certain depth; a depth which depends on the frequency of rain. Even hard rock, when freshly quarried, contains some water; and any excavation, such as a mine or a well, carried to the depth of 30 or 40 feet, in a country such as that drained by the Mahánadi, will be partly filled with water at all times of the year. When absorbed by the surface soil, the rainwater gradually penetrates deeper through the crevices, which exist in all rocks; through the mass of the rock itself, if it be porous and permeable to water; and at a depth which varies with the season and the dryness of the country, a level is reached, below which the rocks and all their cavities and crevices are fully charged with water. So long as this level is higher than the bottoms of the lowest valleys, the water will gradually trickle out of the rock at some lower level, where it can find an outlet; in some places, where the outlet and supply are large, as a permanent spring; at other places merely oozing through the soil. The accompanying diagram will help to elucidate this description.

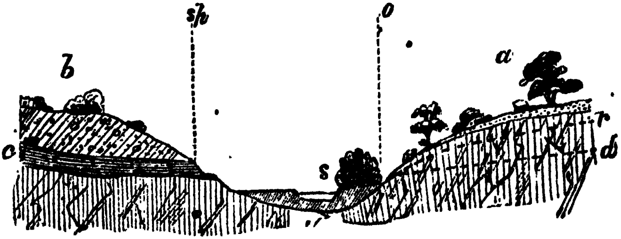

Fig. 12.

The figure represents an ideal section of the ground, across a little valley, drained by the stream at *s*. On the one side *a*, the hill is formed of some hard rock, not itself permeable to water, but much cracked and broken, so that water can find its way from the surface through the crevices. The water thus absorbed will slowly, and in the course of time, trickle out at the hillside at *o*, about at the level of the stream; but this will go on very slowly; and, except perhaps after a quite unusual drought, there will always be a supply of water in the rock above this level. After heavy rain, we may suppose the dotted line *r* will indicate the level below which the rock is saturated with water; while, after a moderately long drought, the level of saturation will have fallen to *d*. On the other side of the valley the rocks are different. A bed of gravel forms the upper part of the hill; and below this is a bed of clay, which water cannot penetrate. In this case, the porous bed of gravel will hold a large quantity of absorbed rainwater; which, being stopped by the clay bed at *c*, will gush out at *sp;* forming a perennial spring if the bed of gravel be extensive, or a temporary spring, yielding only after a fall of rain, if it be small, so that the supply is soon exhausted.

This supply from subsoil water is extremely important in a climate like that of the greater part of India, where the rainfall is very heavy during certain months of the year, and very scanty, or altogether wanting at other seasons; and it becomes a question of national importance to prevent its diminution or loss. Unhappily, the destruction of the forests, which has been going on rapidly in many parts of India for many years past, has this effect. Trees shade the ground and shield it from the scorching rays of the sun. At the same time the soil is held together by their roots and those of the smaller vegetation that springs up in a forest; and the soil, thus held and sheltered, serves to absorb rain and transmit it to the rocks below. The effect of clearing the forest is, then, to expose the soil to the baking heat of the sun, and to be washed away by heavy rains. On steep rocky ground, where the soil is scanty, this is soon effected; and the spontaneous reestablishment of the forest is rendered impossible; while, the absorbent covering of the rocks having been destroyed, every shower of rain rushes at once off the hard surface, flooding the rivers for the time, and leaving no provision for that subsoil drainage, which, amid forest-clad hills, furnishes a constant supply to the rivers throughout the rainless season. In parts of France, more especially that known as the Côte d'or, large tracts of country have been rendered sterile and uninhabitable, in consequence of the ignorant destruction of the forests; and there are few parts of India that have not suffered more or less, already, from the same cause. The preservation of forests from general destruction is then a matter of national importance. Once cleared, it is the work of many generations to restore them.

We must now turn our attention to the lower part of the river, the *delta** and its channels. The character of this part of the river, and of the country through which it runs, is very different from that hitherto described. No sooner does the river enter the plain, than its current is retarded; the slope, down which it runs, being so small as to be imperceptible to the eye.† Consequently, it is no longer able to carry with it all the sand and other sediment that it has washed away from the hill slopes in the upper part of its course, and it begins to deposit the excess on the bed of its own channel. Moreover, the country around being on nearly the same level, it is no longer restricted to one channel, but divides up into several, branching out over the plain. Even these cannot contain all the water when the river is flooded; and then they overflow their banks and spread their waters abroad over the low lands around. And now follows a noteworthy result. As soon as the waters have left the river, their motion decreases. More sand and silt is deposited; and it is deposited most abundantly close to the margins of the channel, raising the banks higher than the general level of the plain. A section across a river in its delta is, therefore, such as is represented in the accompanying figure; which contrasts strongly with that of the stream with its valley represented in figure 13. In Katak, the banks of each

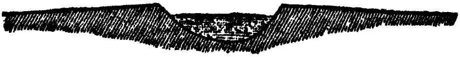

Fig. 13.—Section of a Deltaic River.

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* The term *delta* was originally given to the lower part of the Nile, which, below Cairo, divides into two principal branches, now known respectively as the Damietta and Rosetta branches. The triangular tract of flat land, between them and the Mediterranean Sea, resembles in form the Greek letter Δ *delta*. Hence the name.

† See Introduction, p. 5.

stream are further artificially raised, to preserve the country from flooding. But even where this has not been done, the banks of the rivers in a delta are higher than the land round about. In Calcutta, for instance, the drainage of the town is carried not into, but away from, the Hooghly, down the natural slope of the ground to the Salt Lake; and in the eastern districts of Bengal, where the rivers are not restricted by artificial embankments, when the whole intervening country is flooded in the rains, the banks of the river channels generally remain more or less above water.

In the delta of the Mahánadi, as in that of the Ganges, and indeed all large rivers, the ordinary level of the water in the channels is not very much lower than that of the land around. When the rivers are flooded, it is frequently much higher; and I have already observed that, on such occasions, the waters spread over the intervening low lands, and gradually raise them by depositing their silt. But in thickly-inhabited countries, such as Orissa and the Midnapore districts, where the land is under cultivation, it is frequently sought to confine the rivers to their channels by *dykes* or artificial embankments, termed also *bunds*. These suffice to restrain the waters in ordinary seasons, but their effect is not wholly advantageous. The level of the water in the channel is artificially raised, since none can escape; after a time, the bed of the channel also becomes raised by the deposited silt; and in order that the embankments may continue to afford protection, they must be raised in their turn. In the course of many years, a river may thus be raised, till it ordinarily flows much above the level of its delta, and even of the houses of the villages around. Such is the case with the river Po in Italy. Should such a river breach its embankments in an extraordinary flood, it can easily be imagined that the destruction caused by it far exceeds that produced by an ordinary flood in an unembanked river.

The Mahánadi is unenviably notorious for its floods. I have already pointed out how the form and character of its drainage basin favour the rapid discharge of the rainfall; and I have now to point out why it happens that, on such occasions, the rice lands of Katak and Púri are almost inevitably flooded. Some years since a very careful measurement of all the channels of this delta was made by Captain Harris; and the result showed that, taken altogether, they were capable of carrying away only about half the water that comes down in one of the great floods. The excess *must* therefore spread over the country around, despite the embankments of the channels.

In the delta of the Ganges and Bráhmapútra, the land, for many miles inland from the sea, is a marsh washed by sea water at every spring tide, and covered with the vegetation peculiar to such regions; in which mangroves, the Súndri, the Nipa-palm, &c., are predominant; and beyond the margin of the land, the sea itself, for some miles out, is filled with shoals and sand banks, partly uncovered at low water; which are in fact a sub-marine extension of the delta. At some future time, if not submerged deeply by a general sinking of the delta, such as was noticed in Chapter IV (p. 45), these will be converted into marshy islands; while the present Súndarbans will be gradually raised till they become habitable. Such has been the history of all Lower Bengal. There was a time, when the sites occupied by Calcutta, Dháka, Jessore, &c., were covered by the sea; and the shoals first formed off the mouths of the rivers then existing, have gradually been raised by the continuous deposit of river-silt, in the manner described in the preceding pages.

The deltas of the Mahánadi and other rivers of the east coast of the Peninsula are not extending outwards like that of the Bráhmapútra. The Mahánadi delta is indeed as yet not quite completed, for not only is its surface still being raised, but it is gradually filling the Chilka Lake, which is a piece of the sea that has been cut off from it and enclosed by a *spit* of sand. But off the mouth of the Mahánadi there are no great sand shoals, the foundations of future islands, like those that fringe the Súndarbans. The Káveri delta in Trichinápali and Tanjúr represents the final condition, to which that of the Mahánadi is approaching. Very little of this is ever even flooded by the river. It is now so high that it is permanently above the water level, and artificial irrigation is necessary to enable the land to be cultivated. Not a particle of new land is forming in the sea opposite. In fact it is a *finished* delta. All the silt, now brought down by the river, is carried away by the sea currents that sweep up or down the coast; and instead of adding to the delta, it is spread abroad over the floor of the Bay.

The formation of a river delta may be regarded as a struggle between the land and sea. In a quiet land locked bay a delta forms rapidly; stretching out its branching channels, indicated by their emerging banks, like the roots of a growing tree. A chart of the Mississippi delta in the Gulf of Florida well illustrates this, and to some extent the same character is traceable in that of the Kistna and Godávari in the angle of the Indian coast. Even those of the Káveri and the Mahánadi project slightly beyond the general line of the coast. The river, in each case, continually brings down sediment, some of which is deposited wherever the flow of its waters is checked or diminished; and the chief check takes place when it enters the sea. Here therefore a deposit is formed; and it depends on the character of the sea, whether this is distributed over a large area, forming shoals separated by shallow channels; or in a single shoal, termed a *bar*, across the mouth of the river. The former is the case of the Gangetic delta, the latter that of the Mahánadi and all the rivers of the east coast. It is the existence of such bars that renders it impossible for sea-going vessels to enter most of these rivers. A delta ceases to extend outwards, when the permanent currents of the sea are powerful enough to carry away all the sediment that the river brings down.

Tidal currents,* on the other hand, have the effect of keeping open the entrance of river estuaries; and their power is increased if the sea is shallow opposite the river mouth. In passing over this shallow, the tidal wave becomes piled up, as was explained in Chapter III; and as this wave is propagated into the estuary, a large body of water is thrown into the river twice every day, which passes out again at each ebb tide, together with the water the river has brought down in the meantime. A swift current flows therefore in opposite directions twice every day, sweeping away the sediment and keeping the channels open. It is for this reason that the Hooghly remains navigable to the present day. Estuaries such as the Mutlah, which, though at some former time the outlet of some one of the delta rivers, now receives little water from the interior, and therefore little sediment may thus be kept open for an indefinite period by the scour of the tidal currents.

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* See p. 39.

We have now traced out the history of our river, and incidentally we have compared and contrasted it, in certain of its characteristics, with portions of some other large rivers. But the subject of rivers and their action is too large and too important to be fully discussed in a single chapter, and there are other bodies of fresh and also salt water connected with rivers, which remain to be noticed. These we shall deal with in another chapter.

CHAPTER IX.

RIVERS AND LAKES.

In the last chapter we studied the case of a river in a tropical climate, fed exclusively by the periodical rainfall and those surface springs that are the outflow of the absorbed rain. We saw that, as a consequence of these conditions and of the rocky and hilly characters of its drainage basin, the Mahánadi is very full during the three or four rainy months of the year, and is then sometimes subject to very destructive floods, produced by extraordinary falls of rain; while, during the remainder of the year, it contains so little water, that it can be navigated only by boats of the smallest size. Very different is the case of the Indus; a river, the main stream of which derives its chief supply from the melting of the winter snows on the Tibetan Himálaya; while its larger tributaries bring down the summer rainfall of the outer Himálaya in addition to the above. After leaving the mountains, it traverses nearly 700 miles of arid plain, in no part of which does the rainfall exceed 20 inches in the year; while by far the greater portion is absolute desert. The Indus, like the Mahánadi, is subject to a regular periodical rise and fall, and occasionally to extraordinary floods; but the causes being different in the two cases, the periods of their occurrence are different also.

In Chapter II,* it was explained how, during the winter season, the cold air over the plains (and, I may add, the mountain slopes) of Upper India, flows away to the south, forming the wind known as the north-east or winter monsoon; and how it is replaced by a damp wind, which blows from the south in the higher part of the atmosphere, and descends on the Panjáb and the upper part of the North-West Provinces, bringing the winter rains. Over the Himálaya, where the temperature is below the freezing point, the vapour of this wind is condensed as snow, and this accumulates on the mountain summits and in the higher valleys during the winter season. With the increasing warmth in spring, it begins to melt; and the rivers, which in these lofty regions have been silent and frost bound by the intense cold, are once more set free, carrying down gigantic blocks of ice and rock, with large quantities of mud, in an impetuous and ever increasing torrent. Collecting gradually in the larger tributaries, and then in the main stream, by the month of February the swelling waters reach the plains of the Panjáb; and the stream, which has been shrinking since the previous July, and during the winter months has been represented by a number of shallow, scarcely navigable channels meandering through the vast bed of the river, begins to swell and sweep away the *churs*, now covered with grass and bulrushes, which accumulated at the close of the previous season. During the succeeding months, the volume of the river increases, as the snows are more copiously melted; and when, in July, the heat of the Panjáb and the mountain cradle of the river has reached its highest point, and when the summer rains are falling heavily in the Kángra and Hazára Hills, the Indus and its great tributaries are in full flood. After this, the waters decline, and reach their lowest level by October.

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* Page 26.

The extraordinary floods, to which the Indus is subject, appear to be due, not to excessive rain or any unusually rapid melting of the snows, but to some one or other of its larger tributaries being temporarily blocked up, either by the advance of a glacier or the fall of a portion of a mountain; so that a barrier is thrown across the valley, and the river waters dammed up behind it. Under such circumstances, a lake is formed behind the barrier; and continues to swell, until the water succeeds either in over-topping it, or in silently undermining it, when it at length bursts, and the pent-up torrent, suddenly set free, rushes downwards once more with overwhelming impetuosity and power.

The following graphic account of a great flood of this kind, which occurred in the beginning of June 1841, and was witnessed by Ashraf Dhan of Torbela, is given by Major Abbott in the words of the narrator: "At about 2 P.M.

a murmuring sound was heard from the north-east among the mountains, which increased until it attracted universal attention, and we began to exclaim 'What is this murmur? Is it the sound of cannon in the distance? Is Gandgarh bellowing? Is it thunder?' Suddenly some one cried out 'The river is come!' and on looking, I perceived that all the dry channels were already filled, and that the river was racing down furiously in an absolute wall of mud, for it had not at all the colour or appearance of water. They who saw it in time easily escaped; they who did not, were inevitably lost. It was a horrible mass of foul water, carcases of soldiers, peasants, war-steeds, camels, tents, mules, asses, and household furniture, in short every item of existence, jumbled together in one flood of ruin; for Raja Golab Singh's army was encamped in the bed of the Indus at Kulai, three *kos* above Torbela, in pursuit of Paindu Khan. Part of the force was at that moment in hot pursuit, or the ruin would have been wider. The rest ran: some to large trees, which were all soon uprooted and borne away; others to rocks, which were speedily buried beneath the waters. Only they escaped who took at once to the mountain-side. About five hundred of these troops were at once swept to destruction. The mischief was immense; hundreds of acres of arable land were licked up and carried away by the waters. The whole of the Sisú trees which adorned the river's banks, the famous Bargah tree of many stems, time out of mind the chosen bivouac of travellers, were all lost in an instant."

On this occasion, according to Major Montgomery, the cause of the flood was a landslip in the Gilghit valley. The valley was blocked up by an enormous mass of earth and rock that had slipped down from the side of a mountain; and a lake was formed behind it, which is believed to have been 800 or 900 feet or more deep. At last the barrier gave way, and the whole mass of pent-up water was suddenly discharged down the valley.

Another great flood, arising apparently from a similar cause, occurred in August 1858.

In describing the Mahánadi in the previous chapter, I observed that the valley in which each stream flows is the work of its own waters. It is in the Himálaya that we have the grandest examples of this kind of river action; and this will be the most convenient place to describe it somewhat more in detail. In the loftier valleys, in the neighbourhood of the permanent snows, glaciers are powerful agents in eroding and excavating the rocks over which they pass. The masses of rock which are carried down by the ice stream, firmly frozen in the ice, are dragged over the bare rocks of the sides and bed of the glacier, grooving them and grinding them down with perfectly resistless force. The sand and mud so produced are carried away by the stream which issues from the end of the glacier, gushing out from an ice cavern at its foot, turbid with glacier-mud. In former times the Himálayan glaciers extended far below their present limits, and they have performed no unimportant part of the excavation of the great river valleys. In the Tísta valley in Sikkim, glaciers do not now extend below 14,000 feet, but traces of their former work are still visible down to 6,000 feet above sea-level; while in the Kángra valley in the north-west Himálaya similar indications are met with as low as 3,000 feet above the sea.

But the river itself is also a powerful excavator. Rushing down steep slopes with a high velocity, it has power to roll along pebbles and even large masses of rock, grinding them against each other and over its rocky bed, and insensibly wearing down the latter, however hard may be the rock that forms it. In a hard rock the river excavates a *gorge*, with precipitous sides, very narrow, but sometimes of great depth. Such is the remarkable gorge at the junction of the Sutlej and Spiti rivers. Where the rocks are less hard and stubborn, the sides of the valley become more sloping under the action of frost and the atmosphere. The surface of the rock is splintered and falls, and the fallen mass is gradually ground up and borne away by the torrent.

Rocks differ extremely in their power of resisting decomposition. In certain cases it would seem that, after exposure for centuries to the action of rain and frost, they present the same unyielding surface, unchanged in form and texture. In other cases, frost and rainwater, aided by those chemical constituents of the atmosphere called carbonic acid gas and oxygen, not only disintegrate the whole superficial mass of the rock, reducing the hard stone to the state of clay and gravel, but carry this action far into the heart of the mountain. Where this has taken place, the excavation of the valley goes on rapidly. From time to time, especially after heavy rainfall, enormous masses of earth and rocks, becoming saturated with water, slide down the mountain side, carrying everything before them; and after blocking the valley for a time, are carried away by the ceaseless action of the stream. In this way, as was pointed out above, are caused some of those sudden floods of which two extraordinary examples were quoted.

In a country such as British Sikkim, where the rainfall is great, the rocks easily decomposed, and the forest growth exceedingly luxuriant, the form of the mountain slopes is almost entirely due to landslips. In the neighbourhood of Darjiling, after each heavy fall of rain, the hill-roads are generally interrupted in many places by little falls of this kind; and sometimes the mountain-side to a height of 3,000 or 4,000 feet is seen freshly exposed, the whole of the surface with the forest that covered it having been precipitated into the valley below.

By these various agents, frost, rain, carbonic acid, and finally gravitation, the original hollows and inequalities of the newly raised mountain mass have been connected, and further carved and excavated, so as to form a complete system of valleys, separated by mountain ridges. The materials carried away in the process have been partly deposited in the original hollows, as great gravel deposits, such as are seen everywhere in the valleys of Ladákh, and that through which the Sutlej has excavated its valley in the Tibetan province of Guge; but the greater part, when ground down so fine that they could be carried out into the plains, have been spread abroad by the rivers, forming the arable lands of the Gangetic plains. These plains then are formed of the waste of the mountains, and though they themselves have also been wasted, and are still being worn away and their materials borne away and deposited in the ocean, they receive on the whole more than they lose, and the greater part of this is derived from the Himálaya. But all the hill tracts of India are subject to the same process of degradation, and so in various degrees are all mountains whatever.

Amid the endless variety of feature presented by rivers, in their course through hilly countries, none is more striking and impressive than their *falls*. A fall occurs whenever, owing to some peculiarity in the geological structure of the country, there is a sudden precipitous descent of the channel, over which the whole body of water is precipitated to a lower level. Among the best known and largest waterfalls in the Peninsula of India are the falls of the Saravati river in Kanara, those of the Yenna in the Mahábleshwar hills, those of the Káveri in Maisur, and that of the Paikára river over the edge of the Nilgiri hills. In the first of these, near the town of Gairsapa, the river is precipitated over the edge of the Western Ghâts to a depth of 888 feet in a single fall. Captain Newbold, who has given a graphic description of the appearance of these magnificent falls, when somewhat swollen by the rains, estimates the quantity of water then discharged over them at 46,000 cubic feet in each second. He says "the falls of Gairsapa may be justly ranked among the most magnificent cataracts of the globe. While excelled in height by the Cerasoli* and Evanson Cascades in the Alps and the falls of the Arve in Savoy, the Gairsapa cataract surpasses them in volume of water precipitated; and while much inferior to Niagara in volume, it far excels those celebrated falls of the New World in height."

The falls of the Yenna in the Mahábleshwar hills are stated by Captain Newbold to be 600 feet in height. Those of the Gokák in the South Mahratta country are 178 feet high, (on the same authority); the river which, a little above the fall, measures about 250 yards across, contracts to 80 yards on the brink of the chasm, and discharges in the rainy season a volume of water, estimated at 16,000 cubic feet per second.

The falls of the Káveri are of less height than the Gairsapa falls, not exceeding about 300 feet; but the volume of water discharged is much greater. In Bandelkand are several well known falls, the largest being that of the Tonse river (200 feet in height) near Chacbai. That of Bilohi about 12 miles west from the Katra pass is 398 feet high, and that of Bouti 10 miles further west is 400 feet in height. At Chera Punji in the Khasi hills, the falls of Mawsmai exceed any of the above, having (according to Dr. Oldham) a sheer fall of 1,800 feet and a broken fall of 1,000 feet more; but except after heavy rain their volume is insignificant.

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* The height of the Cerasoli cascade is 2,400 feet; that of Evanson 1,200 feet; and the falls of the Arve 1,100 feet.

Lakes are natural depressions in the surface of a country, in which the drainage water accumulates; either until, having filled the depression up to the lowest part of the encircling ridge, it reaches a channel by which the excess can flow away; or else until it exposes so large a surface, that the natural evaporation from that surface is equal to the total quantity of water flowing into the lake in the same time. The latter case can occur only in a dry country, where the rainfall is small and the evaporation rapid in consequence of the dryness of the atmosphere. The result is, that the water of such lake is salt: for since all the drainage water that reaches the lake carries some small quantity of salt dissolved in it, and the water eventually evaporates, leaving behind all non-volatile substances, the salt must accumulate in the lake. There are many such lakes in the great region in Central Asia to the north of the Himálaya, and even in the Tibetan Himálaya itself; as for example the Pangong lake in Ladákh near the Upper Indus valley. It appears from Major Godwin Austen's account, that this lake was formerly one of fresh water, from which a stream flowed into the Shayok, a tributary of the Indus. Owing, however, to the increasing dryness of the country, (of which there is abundant evidence, though the cause is as yet unexplained,) it is now isolated and much shrunken in size, and at the lower end is quite saline. The Caspian Sea and Sea of Aral are instances of salt lakes, being quite isolated from the ocean, and of such size as fairly to deserve the name of inland seas. Another and smaller example is afforded by the Dead Sea in Palestine, which occupies the bottom of a remarkable depression; such that the surface of the lake is 1,312 feet lower than that of ocean. It appears probable that, at one time, the valley of the Jordan, (which river flows into the Dead Sea,) was in communication with the Gulf of Akabah and the Red Sea; and that it has been isolated by the elevation of the desert of Petræa, and subsequently dried up. The waters of the Dead Sea are *saturated* with salt: that is, the water is incapable of holding more salt than is actually dissolved in it, except at the end where the Jordan enters it; no fish or other animal can live in its waters, and it is hence emphatically called the 'Dead Sea.'

In Rájpútána, on the borders of the Bikanír desert, are some small salt lakes, the largest of which is the Sámbar Lake. This is a shallow depression, filled by the annual monsoon rainfall, (which here does not exceed 20 inches,) and then drying up. The salt obtained from it is an important article of commerce in Rájpútána. Another salt lake yielding a salt of a different character is that of Lunár in Berár. It forms a deep crater like depression, and is thought to be of volcanic origin.

Lakes which have an outlet invariably contain fresh water; unless, like the Chilka Lake and other similar lagoons along the coast, they communicate directly with the sea, so that sea water can enter them. There are but few instances of natural lakes of fresh water in India; almost the only examples are certain little mountain lakes, such as that at Naina Tál and those below the Yaklá and Cholá Passes in Sikkim, lately discovered and described by Mr. W. T. Blanford. Beyond the snowy range, the Manasarovar and Rakhas Tál Lakes are larger instances of the kind. It is improbable that any of these are original rock basins; that is to say, hollows left in the disturbed rocks at the time when the mountain mass was upheaved. In some cases they appear to lie in hollows, worn by the friction of former glaciers in their rocky beds, and filled with water after the retreat or disappearance of the glacier. In other cases they are portions of old glacier valleys across which an old moraine forms a natural embankment or *bund;* and in others again, such as the Tso Moriri and the Pangong Lake in Rakshu and Ladákh, they appear to occupy portions of a valley, the drainage of which has been arrested by a mound of alluvial deposit, brought down by a mountain torrent from the lateral mountain ridge.

These remarks apply only to the lakes of the Himálaya and similar mountains elsewhere. Such great lakes as those of Canada, and those in East Africa on the upper Nile, the Tanganyika, &c., may possibly be original rock basins, formed during upheaval: and those that cover Finland and North-Western Russia may be depressions in the old sea-bottom left as such when the country was elevated above the sea.

The shallow swampy lakes that occur in certain river deltas, such as the salt lake to the east of Calcutta, are more properly termed *lagoons;* and the same term is applied to those sheets of *brackish* or saltish water that occur on certain parts of the coast; of which the Chilka Lake in Orissa and the Pulicat Lake to the north of Madras are good examples. The former of these are portions of the delta lying between the river channels; and which the sediment deposited in them, year by year, has not yet sufficed to fill up to the ordinary dry weather water-level. In some cases, such as that of the example cited, they are more or less salt, because they communicate by certain channels with the sea, so that salt water passes into them at every tide. The Chilka and Pulicat Lakes have been formed in a different way. They are separated from the sea by a ridge of sea sand, termed a *sand-spit,* and formed of sand drifted up the coast by the current noticed at page 40. To take the case of the Chilka: the sand accumulating along the shore of Ganjam and other more southerly parts of the coast, is gradually drifted northwards by this current, being added to by the sediment of every river that discharges itself into the Bay. At some former time, the sea must have washed the base of the hills that lie to the west of the Chilka; but this having become shallow by the sediment poured into it by the Mahánadi and the smaller streams from the interior, a sand bank was formed by the coast current, tailing off from the southern extremity of the lake, until the lagoon behind it was almost completely enclosed. The sea alone could not raise this higher than the sand could be washed by the breakers; but as a part of it would be laid bare and dried by the sun at every ebb tide, the dry sand would be caught by the winds blowing from the sea, and raised in long mounds or *sand hills*, rising 20 or 30 feet above the highest wash of the waves. In the course of time, various creeping plants which flourish on sand have taken root on the surface thus raised; the seeds being carried by the wind. These have fixed the sand, and by their decay have formed vegetable mould, fit for the nutriment of other plants, such as grass and the dwarf date palm; and finally, as the spit has increased in width by further accretions on the seaward face, the older surface has been brought under the plough, and has become arable land.

A channel however remains, through which the tidal waters pass and repass to the lake; and through which also the flood waters of the latter escape, when the surface of the lagoon has been raised by the rivers and streams that discharge into it during the rainy season. At such times its waters are almost or quite fresh; but during the greater part of the year more or less sea water is intermingled, especially in the neighbourhood of the outlet channel, rendering them saline or *brackish.* Year by year, these lagoons become shallower, since most of the sediment brought in by the streams from the land is deposited on the bottom of the lake; and in the course of time, they will be filled up and will be converted into dry grassy plains. Some miles to the north of Pondicherry, near the village of Mercánum, there is such a lagoon, now nearly filled, and a great part of the low plain that extends at intervals along the Madras coast has been formed in this way and subsequently elevated.

In the last three chapters, we have reviewed briefly the work done on the surface of the earth by the waters condensed from the vapour of the atmosphere. Glaciers and rivers wear down the mountains, and plough out those valleys through which the waters find their way downwards to the sea; frost splinters and cracks the rocks; and rain water, dissolving the carbonic acid of the atmosphere, penetrates them and works chemical changes in their mass, by which they are decomposed; some part of their constituents being dissolved by the absorbed water, while the residue, having lost its rigidity and hardness, yields easily to gravitation and the friction of running water. The materials, derived from the waste of the mountains, are spread abroad over the low plains at their foot, or carried further out to form river deltas, or finally to settle down on the sea bottom.

In most countries then, in *all* where the atmosphere is moist and the precipitation as rain or snow is abundant, the form of the surface is largely modified by these agents. And even in those arid regions where no rain falls, the deserts of Central Asia, the Sahára and the coast of the Red Sea, the deeply scored sides of the mountains and tortuous *wádis* bear testimony to their former activity. These countries were not always so arid and rainless as they now are. In times geologically recent, both the Sahára and a great part of Central Asia were occupied by the sea; the remnants of which, (in the latter case,) we have in the existing great salt lakes the Caspian and the Sea of Aral. When these seas existed, their evaporation furnished rain, which falling on the slopes of the Atlas, the Atlai and the Thian Shan, shaped and fashioned these peaks and ridges, much as the Himálaya is now being shaped and fashioned by the waters condensed from the evaporation of existing Indian seas.

Carrying our thoughts onwards from these agents to the causes which produce them and give them power, we find that the ulterior agents, whose work is thus unceasingly to wear down the land surface to one uniform level, are no other as those whose work they thus destroy. Heat and gravitation break up the earth's surface, causing continents to protrude from the ocean, and thrusting up broken and contorted layers of rock to form their mountain skeletons; and heat raises the ocean waters as vapour, which condensed on the cold mountain sides, gravitates again to the sea, and wears away the surface in its passage. But the heat that upheaves mountains is the primeval heat of the earth, that which planes them down is the heat emitted by the sun.

CHAPTER X.

THE PHYSICAL GEOGRAPHY OF INDIA.

I.—The Peninsula.

IN the foregoing chapters of this little treatise, after a brief review of the relations of our earth to the other bodies of the solar system, we turned our attention successively to what is most noteworthy in the atmosphere, the sea and the land. In so doing, I have, wherever possible, selected our illustrations from the things immediately around us; since things and places that we can see and examine for ourselves, are not only more interesting to us than those which are far off, but are the only ones concerning which we can have any real and familiar knowledge. To know thoroughly what can be known respecting the country we live in, is the best possible preparation for travelling to foreign lands. Having been accustomed to observe the things amid which we have lived, and to systematize our observations on entering a new country, we are neither bewildered by its strangeness nor confused by the multiplicity of noteworthy objects. We have already acquired mental standards of comparison, by which to distinguish the important from the trivial. Each new fact that strikes us falls at once into its proper place in our mental storehouse, and helps to correct some error of conception, or to extend a generalization previously thought out. Travel, instead of wearying, becomes the source of ever-renewed interest and pleasure, and we return with enlarged views and strengthened mental powers to the scene of our earlier experience. Science is no exotic. There is no land that does not teem with interest to him who knows 'how to observe;' and although, in that science which now engages us, there are some subjects of great importance, that can perhaps be studied more advantageously elsewhere than in India; it may, on the other hand, be truly said, that no country offers a greater variety, and at the same time grander examples of some of its principal phenomena.

As a sequel therefore to the general description in the foregoing pages, we will, in these concluding chapters, take a rapid review of the Physical Geography of India. We shall first note the form of the land and the direction and position of its mountain ranges; and as far as our present knowledge enables us to determine, the geological antiquity of the rocks that enter into its structure. We shall at the same time trace out the relations of the great river basins to the hill ranges and the form of the surface; and finally we shall show how the movements of the atmosphere, and therefore the variations of the rainfall and the climate, are affected by these and other circumstances. We shall confine our attention to those branches of Physical Geography that have been discussed in the foregoing pages; leaving aside all the more difficult and recondite parts of the science, such as magnetism and electricity, the botany and zoology of India, its mineral and other useful products, and the natural history of its human inhabitants; since these require more preparatory knowledge for their proper understanding, than can be conveyed in a little rudimentary treatise such as the present.

First observe that, at the foot of the great mountain ranges which cut off India from the rest of the Asiatic Continent, viz., the Hála and Sulaimán ranges, the Himálaya, and that which in Eastern Bengal rises from the swamps of Silhet and Maimansing, a broad belt of plain sketches across from sea to sea. This plain completely isolates the ancient highlands and hill groups of the Peninsula, from the more imposing but more recent encircling chain; and it will be convenient to describe them separately.

Any good map of India will show that the peninsular portion is traversed by two principal mountain chains; one running somewhat obliquely across it, in a nearly east and west direction, from the Gulf of Kambai to Amarkantak; and after an interval, rising again in Sirgujah and running through Chutia Nágpúr and Hazáribágh to the western limits of the Gangetic delta; the other, almost at right angles to the former, running from the mouth of the Nerbudda to the southern extremity of the peninsula. The former may be termed the Sátpúra and Chutia Nágpúr ranges, the latter is that of the Sahyádrí or the Western Ghâts. Besides these, a series of hill groups, separated by intervals of low country, extend in a north-east and south-westerly direction along the east coast. These are frequently termed the Eastern Ghâts, but they are not continuous; and although in some parts rising to more than 4,000 feet above the sea-level, as a geographical feature they are of less importance than the first named ranges.

These ranges may be regarded as the skeleton on which the form of the country chiefly depends. South and north of the Sátpúras extend two great plateaux. The northern is separated from the range itself by the valleys of the Nerbudda and the Sôn; along which it terminates by a steep abrupt escarpment, now termed the Vindhya range,* on the north of the former, and the Kaimúr range along the latter, river. At the summit of this escarpment, the edge of the tableland is in some places 2,000 feet above the sea; and the surface slopes thence towards the Ganges valley, into which it is drained by the Chambal, the Sindh, and the Kén rivers. On the west, it terminates at the Aravali range, 3,000 to 4,000 feet high, which declines to the Thar desert. Mount Abú in this range rises to 5,000 feet.

The southern and larger plateau is not more than 1,000 feet above the sea at Nágpúr; but rises to the westward, till it attains to about 2,000 feet on the edge of the Western Ghâts; where certain hills, such as that of Mahábleshwar, reach to heights of upwards of 4,000 feet. Further south, the surface declines towards the Tungabhádra valley, but rises again in Máisúr to 2,000 and even 3,000 feet, terminating in the lofty hill group, the Nilgiris, with an average elevation of 7,000, and one peak (Dodabetta) of 8,760 feet. To the south of the Nilgiris, beyond the Pálghát Gap, and to the east, are grouped several massive hill clusters, some of them almost rivalling the Nilgiris, and offering to the rare visitor some of the wildest and most picturesque scenery in the Peninsula.

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* I say "*now* termed the Vindhya range." It is by no means clear that this is identical with the Vindhya of ancient writers, which divided Hindústán from the Dakhan. Professor H. H. Willson is of opinion that the name was formerly applied to the Sátpúrás.

The direction taken by the drainage has been determined mainly by the two mountain ranges first described. The Western Ghâts constitute the principal water-shed of the peninsula. Their crest is the *highest continuous level*; so that while their steep western slopes and the narrow plain at their foot are drained into the Arabian Sea, the great plateau to the eastward, occupied by Máisúr, Haidarabád, the Dakhan and Nágpúr, with the broader plains of the Carnatic and Orissa, and the whole of the Eastern Ghâts, are drained into the Bay of Bengal. The Sátpúra and Chutia Nágpúr ranges constitute, not one only, but either two or three parallel water-sheds. The northern slopes of the Rájpípla and Sátpúra proper, with the Pachmari and Mandla hills, are drained by the Nerbudda, which flows westwards parallel with the axis of the chain: and the crest of the Vindhyan escarpment, which runs parallel with the river 20 or 30 miles to the north of it, is the limit of its basin in that direction; since all the plateau of Málwá and Bandelkhand, of which this range is the southern boundary, slopes towards the north, and throws its drainage into the Jamna and Ganges. On the south of the Rájpíplas and the Sátpúras, another river, the Tapti, with its tributary the Púran, also runs parallel to the chain; and, like the Nerbudda, flows westward, and discharges its waters into the Arabian Sea. The crest of the Sátpúra, therefore, is the water-shed between the Nerbudda and the Tapti. South of this latter river is a third water-shed, formed by the Indhyádri hills, also parallel to the river and the two former, and dividing its waters from those of the Godávari basin.

The water-shed of the eastern or Chutia Nágpúr ranges, which, in Sirgujah, separates the Mahánadi from the Sôn, has already been described in a previous chapter. To the east of Sirgujah the hills spread out and form a broad plateau between the Sôn and the Gangetic delta. The greater part of this is drained by the Damúda; the watershed of which separates it, on the south from the basins of the Bráhmaní, the Súbanrika and other smaller rivers; and on the north from the Ganges and some small streams flowing into the Húglí.

Thus the Sátpúra and Chutia Nágpúr ranges, which are indeed rather broad tracts of hill country than definite mountain ranges, have in both cases an independent local drainage system; while they divide the river basins of the Peninsula from that of the Ganges.

The principal rivers of the Peninsula are the Mahánadi, which has been already described in detail; the Godávari and Kistna or Krishna, the tributaries of which drain the high plains of Nágpúr and Haidarabád and the Mahratta country to the westward; the Pennair and the Káveri draining the high tableland of Máisúr and the still loftier plateau of the Nilgiri hills. The basins of these rivers are not separated by very strongly marked hill ranges, or other striking geographical features; except to the eastward, where the several hill ranges, called the Eastern Ghâts, occupy the intervals between their outlets. Thus, between the mouth of the Mahánadi and that of the Godávari, intervenes the hill groups of Jaipúr and Bastár; between the Kistna and the Pennair, the Nullamullais and Vellakondas of Kadapa and Karnúl; between this last and the Púniar, the hills of Pulicat; and the Shivarais and other hill groups of Salem and North Arcot between the Puniar and the Káveri.

The rock formations that enter into the structure of this part of India are the following, beginning with those now actually forming; the others in order of increasing antiquity:—

1*st.*—Certain superficial soils. Modern alluvial deposits of the rivers. Blown sands of the coast.

2*nd.*—Gravels containing rude stone implements of human manufacture. Old alluvial deposits of the great river valleys, containing bones of *extinct* animals and shells of *living* species of freshwater *Mollusca*, together with rude stone implements. Travancore deposits, containing marine shells, all of existing species. Upraised beds, containing shells of existing species, at many points on the Madras coast.

3rd.—Beds of sandstone termed the 'Cuddalore sandstones,' sometimes containing petrified wood, in Trichinopoly, South Arcot, Madras, and also in Bírbhúm.

4th.—Fossiliferous deposits of older *tertiary** or *eocene* date, at Surat and also in Kach'h,

5th.—The great volcanic formation of Western India. The beds of fresh water origin, containing shells, intercalated between the trap-flows; and a deposit near Rájámahendri containing marine shells,

6th.—The richly fossiliferous shales, sandstones and limestones, of *cretaceous* age, in Trichinopoly and South Arcot. The fossiliferous limestone and sandstones, immediately underlying the trap-flows, in the lower part of the Nerbudda valley, (the 'Bágh beds' of the Geological Survey): and probably a calcareous bed and sandstones, in a similar position, on the south of the Nerbudda valley near Jabalpúr, (the 'Lamétá group' of the Geological Survey).

7th.—Fine shales containing remains of Cycadeous plants, in Trichinopoly, Madras, Nellúr, the Rájmahál hills, Central India (near Jabalpúr) and Kach'h. These are probably of about the same age as the Wealden of Europe, or partly perhaps *upper jurassic.*

8th.—The highly fossiliferous *jurassic* formation of Kach'h.

9th.—An enormous series of deposits in Central India and Bengal, apparently of fresh water origin, for which the name 'Gondwána series' has been proposed by Mr. Medlicott. The upper part consists chiefly of massive sandstones, while the lower contains numerous beds of coal. These represent altogether a very long geological period, extending probably from the *Devonian,* or *Lower carboniferous,* to the *Upper Jurassic* epoch, (including the Jabalpúr beds mentioned above under Section 7). There appears to be no discontinuity of importance in this great series, though there are evidently local interruptions. Having regard to these, the following subdivisions have been established provisionally by the Geological Survey:—

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* For the order or relative antiquity of the great recognized standard formations referred to in this and the succeeding chapter, see the article *formations* in the Glossary at end.

In the Godávari basin.	In the Sátpúras.	In Bengal.
	Jabalpúr group ...	Rájmahál beds.
	Bágra & Denwa beds.	
† ? Kota beds ...	Mahádeva or Pachmari sandstone.	Mahádeva sandstones
† ? Mangáli shales ...	Álmod beds ...	† Panchet group.
Kámthi group ...	† Bijori beds ...	Rániganj group.
	Motúr beds ...	Iron shales.
Baráckar group ...	Baráckar group ...	Baráckar group.
Talchír group ...	Talchír group ...	Talchír group.

Fossil remains of animals have been found only in the formations marked†, and they are those of either fishes or *amphibians.*[*] In the remaining formations, with unimportant exceptions, only the remains of plants have hitherto been met with. The position of the deposits marked with a (?) has been inferred from the character of their fossils, and has not yet been verified.

10*th.*—A large and important series of rocks, consisting of sandstones, shales and limestones, in which no fossil has hitherto been detected. They form a great part of the plateau of Bandelkhand and Málwá, between the Nerbudda and the Ganges; and especially stand out in the Vindhyan escarpment on the southern edge of the plateau. Hence the series has been termed the 'Vindhyan formation.' A lower member of the formation covers also the plain of Chattisgarh, and is largely developed in Karnúl, parts of the Godávari basin and in the South Mahratta country.

11*th.*—A series of still older deposits, also quite unfossiliferous, very extensively developed in the Sôn valley, Northern Bandelkhand and Gwalior, also in Singbhúm and Kadapa, underlying the Vindhyan series. These are termed the 'Bijáwar series.' They are frequently much metamorphosed.

12*th.*—The ancient metamorphic (gneiss) rocks which lie at

[*] The group to which belong the frogs and toads, which differ from reptiles, since, during a part at least of their life, they resemble fishes in their mode of existence. In the later *Palæozoic* and early *Mesozoic* times, animals of this kind appear to have been abundant and of large size.

the base of all the above. In Southern India, Messrs. Foote and King have shown these to consist of old stratified rocks bent up in enormous folds, the form of which has an evident relation to that of certain of the hill groups, especially those of Salem and Trichinopoly. In many places they are so highly altered that they resemble rocks of the granitic class.

The lofty hill groups of Travancore (the Palnais, Anamallais, &c.); of Máisúr (the Nilgiris); of Salem and Trichinopoly (the Shivarais, &c.); which average from 3,000 to 7,000 feet in height, and include peaks of more than 8,000 feet, consist entirely of the ancient gneiss. The whole plateau of Máisúr, 2,000 or 3,000 feet above the sea, and the greater part of the low country around and between the hills, are formed of the same rock. These hills appear to be the remains of a mountain range of extreme antiquity, since it is from the waste of these rocks that the only *less* ancient stratified deposits (the Bijáwars and Vindhyans) of the Nágari and Púlicat hills and the Nullamallais have been formed.

Another hill region, of very high antiquity, is that of which we have remnants in the Chutia Nàgpúr and Hazáribágh plateau, the higher parts of which are 2,000 feet above the sea; while some isolated hills, such as Párasnáth, attain to an elevation of more than 4,000 feet. It is as yet uncertain whether the gneiss, of which this consists, is as old as that of Southern India. Mr. Medlicott, the best authority on the subject, is of opinion that it may consist, in part at least, of rocks of the Bahár slate series (No. 11 *supra*) very highly metamorphosed. In any case, this seems to have been mountainous land at the time that the Vindhyan rocks of Bandelkhand and Chattisgarh were being deposited around it; and many of its existing depressions, the valley of the Damúda for instance, and that which separates the hills of Sirgujah from those of Mandla, must have been formed before the commencement of the *carboniferous* epoch, since the Talchír and succeeding rocks, which cannot be regarded as newer than the *carboniferous* period, have been deposited in these hollows.

The upland plains around Nágpúr, averaging 1,000 feet above the sea, also consist of gneiss; as well as the base of the Mandla hills, which are connected on the north-east with the gneissic plateau of Chútia Nágpúr.

Amid all the successive changes of level that must have modified the physical geography of the country, these ancient hill masses have continued to form its principal feature; at one time perhaps as lofty mountains ever yielding to the erosion of rain and rivers; at other times, as hilly islands washed by the sea. The latter was possibly their condition during a part of the *cretaceous* period, when the sea covered the present plains of Trichinopoly and South Arcot, and occupied what is now Eastern Bengal and the Himálaya as well as the western borders of Central India.

But there is some reason to believe that, at a very early period, and perhaps up to this or a somewhat later date, this ancient land was connected with the Seychelles Islands, and at one time even with Southern Africa. Certain animals, whose remains are found fossil in the Panchét rocks, are closely related to kinds hitherto only met with in South Africa and Australia, in rocks of about the same age; and in the existing *fauna** of India there are many indications of relationship, and some cases of identity, with the South African and Seychelles fauna, pointing to a common origin, and therefore to a former communication between the two regions.

In the latter part of the *cretaceous* period, or perhaps at its close, took place that enormous outburst of volcanic activity that has covered 200,000 square miles of country with layers of lava and volcanic ash. Indeed, the area originally covered must have been greater than this; for an unknown extension of these rocks to the westward is now covered by the sea. The old cretaceous sea bottom had been upraised and had formed dry land for a considerable period before it was buried beneath the flow of molten rock. The centre of volcanic activity appears to have been in what are now known as the Rájpípla hills; this has been inferred by Mr. W. T. Blanford from the inclination and disturbance of the trap beds in that region, and the abundance of dykes, which are the ancient channels of issue. Any volcanic cones that may have existed at the time have long since disappeared. In the intervals of the eruptions, fresh water lakes were formed in the depressions of the lava flows; and the deposits formed in these were covered up by subsequent sheets of lava. Several kinds of fresh water

* For the explanation of this term see Glossary.

shells, and some remains of seed vessels and other parts of plants have been obtained from these deposits. Only at Rájamandri is there a marine deposit of the same age.

For a long time after the close of this volcanic period, the lava beds were subject to denudation by the action of the sea, and it is probable that about this time began that subsidence which buried their western extension beneath the sea. There are deposits of *eocene* age at Bharúch and Surat, and also in Kach'h, which shows that these portions of Western India were then covered by the sea: and such was also the case of the Indus and Gangetic valleys, and with much of the region now occupied by the mountains around. But all the remainder of India was probably land, and it may be doubted whether it has ever since been depressed beneath the sea with the exception of the plains lying along the coast and some of the lower hills. The great range of the Western Ghâts is considered by Mr. W. T. Blanford to be an old sea cliff. If so, it must have been formed during the *tertiary* period, and the Konkan must, for a long time, have formed the bottom of the sea. The Tapti and Nerbudda valleys, except perhaps the upper part of the latter, have been re-excavated since the volcanic period, for they are cut through the trappean rocks, and the same is true of the upper tributaries of the Godávari and the Kistna, the Wárda and Pain Ganga, the Bhíma and the Sína.

The alluvial plains along the east coast of the Peninsula have been formed by the deposition of sediment brought down by these and the other rivers that drain the interior. At one time, the coast line must have been very irregular, stretching back to the hills of the Eastern Ghâts; and the low country of the Payan Ghât was being planed down by the sea. It was then, (during some part of the *tertiary* period) that the 'Cuddalore sandstones,' were deposited. Finally this sea bottom was elevated; and the irregularities in the original coast line, thus produced, have been filled up by the deltas of the great rivers, or, being enclosed by sand spits in the manner described in the last chapter, the lagoons left behind them have been gradually filled and then elevated.

Such is a brief sketch of the form and geological history of India south of the Ganges.

CHAPTER XI.

THE PHYSICAL GEOGRAPHY OF INDIA.

II.—*The Himálayan Zone.*

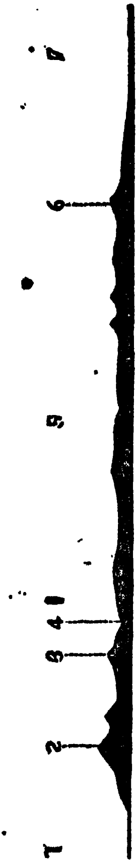

Fig. 14.—Section across the Tibetan Plateau.*

The Himálaya is the mountainous border of the great tableland of Tibet, the loftiest in the world. A section of this elevated mass, from the desert of Gobi to the Gangetic plain, would somewhat resemble the accompanying figure, except that, in the figure, the heights are greatly exaggerated in comparison with the horizontal distances. Of the greater part of Tibet our knowledge is very small. It is known to be mountainous, to be partially drained into a number of salt lakes, and to be bounded on the north by a mountain chain known as the Kuenlún, at the foot of which lies the great desert of Gobi or Shámo. Our knowledge of the southern and western portions is more considerable, though far from complete; and many important problems relating to the origin and courses of the great rivers that drain it, yet remain to be solved by future explorers.

It may be seen on the map, that the direction of the Himálaya is not the same throughout. From the gorge of the Dihong in Upper Assam to the Gandak, it runs nearly west, with a slight curvature, convex towards the plains of India; and beyond this it curves to north-west as far as the valley of Kashmír. It consists of several parallel but not continuous ridges, and the subordinate ridges or *spurs* which these give off in a more or less transverse direction. The loftiest of these principal ridges is about 60 or 70 miles distant from the plains. It includes or is connected by spurs with the gigantic peaks, Chamalâri, Kanchinjanga, Mount Everest (the loftiest known mountain in the world), Doulagiri, and Nanda Devi, the lowest of which is but little under 24,000 feet, while the others vary from 25,700 up to 29,000 feet above sea-level.

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* The figures indicate:—1 Gangetic Plain. 2 The Great Snowy Range. 3 The Indian Water-shed. 4 The Sampo Valley. 5 The Plateau of Tibet. 6 The Ken Lún. 7 The Desert of Gobi.

This chain of peaks is spoken of distinctively as the 'snowy range,' [No. 1, Fig. 15,]* and is the most interrupted of all. The peaks enumerated are not directly connected by any intervening range, but are separated from each other by the valleys of several rivers, which drain their eastern and western, as well as their northern, slopes, and the great plains that intervene between them and the lower but more continuous ridge to the north, which is termed by General Strachey the Indian Water-shed. Thus Chamalâri is divided from Kanchinjanga by the valley of the Tísta; the latter from Mount Everest by the Aran (a tributary of the Khússi,) [A. Fig. 15] &c. Further west the northern slopes of the great snowy range are drained by the Bhotiya Khússi, the Bari Gandak and Tri-súl Ganga, and (after an interval in which the snowy chain approximates more closely to the Indian Watershed) by the Satlej [E,] which rises in the Lake Rakhas Tál, and after traversing the great plain of Gúge at the bottom of a ravine 3,000 feet deep, cut by the river in the heart of the plain, escapes through a remarkable rocky gorge below Shipke.

Beyond the Satlej, an important change takes place in the structure of the chain. In the prolongation of the line of the great snowy range, lies the comparatively low range, the Dhaoladhár [3], which runs as far as the Rávi [F], and appears from its geological structure to be the termination of the snowy range of the eastern Himálaya;† while to the north-east of this, the great snowy chain of the western

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* In this chart the position of the principal mountain ranges, or rather their axes, is shewn by strong white lines, the minor ranges and lateral spurs being omitted. The ranges are denoted by numbers, the rivers by the letters of the alphabet. The outer limit of the mountains is indicated by a dotted line.

† Such at least is Mr. Medlicott's view, founded on a consideration of their geological structure.

Himálaya, the Bára Lachá [6], starts from above the junction of the Spiti and Satlej, and runs north-west to the Indus, forming the north-eastern boundary of Kashmír. It terminates in the grand peak of Nanda Parbat. Between the Dhaoladhár and the Bára Lachá, a third parallel range, the Rhotang range [4], originates; and after a break at the Chenáb [G] is virtually continued beyond that river by the Pir Panjál [5], which forms the south-western boundary of Kashmír. The chain termed by Genl. Strachey the Indian Water-shed [2] is but little known to the east of the lakes Manasarovar and Rakhas Tál. It runs parallel with the great snowy range of the eastern

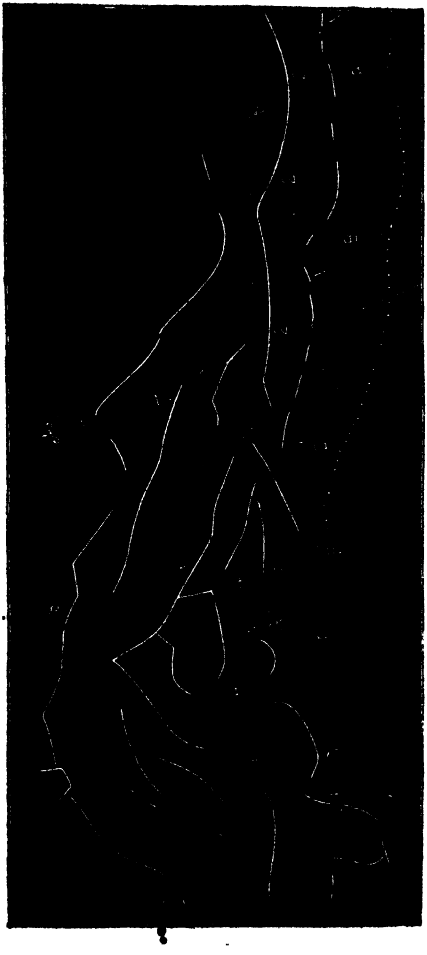

Fig. 15.—CHART OF THE WESTERN HIMALAYA.

Himálaya, but, unlike the latter, is a continuous water-shed, and separates the Aran and other streams already enumerated, from the Yáru Sámpo [K]. This river rises within a few miles of the Manasarovar lake, and flows 200 miles to the south-east, and then 600 miles almost due east, in a valley parallel to the Himálaya; until, as is generally believed, at the 95° meridian of longitude, it breaks through the great chain into Asám, which it enters under the name of the Great Dihong. To the west of the sacred lakes, the Bára Lachá range [6] forms the water-shed, dividing the drainage of the Indus [I] on the north, from that of the Jhelam [H] (in Kashmír) and the Chenáb [G] or Chandra Bhága on the south. North of the Indus, a great chain [7] separates that river from its tributary the Shayok and the Pangong lake; and still further north, the Kárákoram or Mustágh range [8] bounds the valley of the Indus and declines to the plains of Khotan and Yárkand. In this range is the great nameless peak symbolized as K. 2, rising to 28,270 feet, and second only to Mount Everest in altitude: also the great Mustágh glacier and the Kárakoram pass, through which lies the ordinary route from India to Yárkand. Owing to its great altitude, *viz.*, 18,317 feet above the sea, this pass is practicable only during the summer months. The first heavy fall of snow in October closes it to traffic, and it remains impassable till the following May.

From Sikkim westward, the great mountain mass of the Himálaya is bordered by one or more lower ridges of hills of a different geological structure, and generally distinguished as the Sub-Himálaya. The long straight valleys between and behind the ridges are termed Dúns, or Máris in Nepál. Between the Ganges and the Beas the outermost ridge is known as the Sivalik range. The geological and structural relations of the Sub-Himálaya to the greater mountain mass will be noticed presently.

A remarkable feature in the physical geography of the Himálaya, which has attracted the attention of most travellers who have penetrated beyond the great snowy range, is, that the higher valleys are now, or at some former time, have been filled with enormous deposits of sand and gravel. The most striking example of this, hitherto described, is afforded by the upper valley of the Satlej, in the Tibetan province of Gúge, lying to the west of Lake Manasarovar and north of the British provinces Kamaon and Garhwal. It is approached from these provinces by the Niti pass, at an elevation of 17,000 feet. On crossing this pass, says General Strachey, "we find ourselves in a plain, 120 miles in length and varying from 15 to 60 miles in breadth, that stretches away in a north-westerly direction. Its western portion is everywhere intersected by stupendous ravines, that of the Satlej being nearly 3,000 feet deep. The sections, afforded by these, enable us to see that this plain is a deposit of boulders, gravel, clay, and mud of all varieties of fineness, laid out in well-marked beds that run nearly parallel with the surface, and that hardly deviate from a horizontal position." The surface of this great plain is between 14,000 and 16,000 feet above the level of the sea. Similar deposits have been described in the Spiti valley, the Indus valley, &c., but they have there undergone much destruction, and only remnants of them still adhere to the mountain slopes. The valley of Kashmír, at about 5,300 feet above the sea, is another great alluvial deposit, which the river Jhelam and its tributaries are now cutting away, leaving a series of terraces that mark the different levels at which the rivers have once flowed. All these great deposits have been formed from the waste of the mountains around. The most probable explanation of their origin is, that they were deposited in great lakes that occupied the hollows of the mountains before the rivers had completed the excavation of their present valleys. In the Gúge deposits, the bones of various extinct animals are found, deeply buried in the gravels; in such manner, that their remains must have been deposited when the gravels were in course of accumulation. Among others, those of *extinct* species of horse, elephant and rhinoceros; also an animal related to the goat and sheep, and the *hippotherium*, of which no representative exists at the present day.

The Himálaya may be said to terminate in Kashmír, and on the north at the sources of the Gilghit river, a tributary of the Indus. Beyond this to the west, with an exception presently to be noticed, the direction of the mountain ranges is totally different, and parallel to the Indus in the lower half of its course. In Banair and Kafiristán, this direction is approximately north-east and south-west; and further south, where the Indus issues from the Salt-range on the plains of the Panjáb, north and south. The chief exception is the Safid Koh [10], which divides the valleys of the Kábul and Shamil rivers, and runs east and west from Peshâwar up to the tableland of Kábul. Several peaks of this range are 15,000 and 16,000 feet in height. A range south of the Shamil river and one or two other smaller ridges run parallel with the above. Another exception is exhibited in the Salt-range [9]. This is the range at the edge of the little tableland (about 2,000 feet high) which occupies the angle between the Safid Koh and the Sub-Himálaya. It is drained into the Indus by the river Sohan.

The Sulaimán range bears somewhat the same relation to the tableland of Afghánistán that the Himálaya does to Tibet; but both the tableland and its boundary range are very much lower. The highest peak of the Sulaimán range, the Takht-i-Sulaimán, is only 11,300 feet in height, and the city of Kábul, on the northern and highest part of the tableland, is but a little over 6,000 feet.

The Hála range, to the west of Sindh, and running also north and south, is still lower. Bilúchistán, like Sindh and much of Afghánistán, is a very arid country, large tracts being absolute desert. A little vegetation only is met with along the courses of the rivers, which carry down the scanty drainage of the mountains, and generally lose themselves in the sands, or are used up for irrigation, before they reach any permanent stream. This is not the case, however, with the rivers of Kábul, which drain the snowy ranges of the Safid Koh and the Hindú Koh, and are, at all times, well filled streams.

The greater part of Afghánistán is drained by the tributaries of the river Helmand, which discharges itself into the salt swamp called the Seistan lake, on the borders of Persia, and lying 1,550 feet above the sea-level.

Of the countries to the east of the Great Dihong river, at which the eastern Himálaya may be said to terminate, we know but little. But there seems to be little doubt that the great ranges of mountains that run down from the Tibetan tableland have a meridional, that is, north and south, direction; while, in the valleys between them, the great rivers, the Irawadi,* the Yang-tse-kiang and the Mekhong or Cambodia river, carry down the drainage of the snow-capped peaks and ridges that border Central Tibet. To the south and south-east of Asám, the prevailing direction of the principal chains is intermediate between that of the Himálaya and the line of the Irawadi valley. Thus the Pátkoi range, south of Upper Asám, and the Barril range, north-east of Kachár, run north-east and south-west, while the Gáro and Khási Hills between Lower Asám and Silhet run east and west. All the chains of Arakan and Burmah run north and south; and such is also therefore the prevailing direction of the rivers.

We must now turn our attention to the great plain which lies along the foot of these several mountain systems, separating them from peninsular India, and stretching from sea to sea. This, although truly described as a plain, is far from being absolutely level. Its highest point lies at the foot of the Siváliks, between the Jamna and the Satlej, where it is more than 1,100 feet above the sea. It declines from the foot of the hills towards the south, and from the Jamna-Satlej water-shed towards the east; so that at the foot of the Sikim hills and in Lower Asám it is only about 300 feet, at Agra 550 feet, and at Sáhebganj 115 feet above sea level. On the side of the Indus valley, the slope is from north to south (along the line of the Indus); and from east to west, from the foot of the Aravali chain nearly to that of the Hála and Sulaimán ranges. Hence it follows that, while the Ganges flows along the southern margin of its plain, or at the greatest distance from the hills, the Indus flows along the foot of the boundary range. Were the drainage of the Sulaimán and Hála mountains as copious as that from the Himálaya, the alluvial deposits brought down from those mountains would raise the level of the plain at their foot; and, in the course of the time, the Indus would be driven to a distance from these hills, just as the Ganges is from the Himálaya: but, as we have seen, this part of the country is almost rainless.

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* The view here taken of this debatable piece of geography is that advocated in Dr. J. Anderson's Report on the Expedition to Western Yunan.

Immediately along the foot of the Sub-Himálaya, the outward slope of the plain is comparatively rapid. This elevated margin (termed the Bhábar or Bhávar, or Jhéri in the North-West Provinces and Nepál) is formed of the coarse gravel and shingle brought down by swollen torrents from the hills, and deposited, as soon as their velocity is checked, on reaching the plains. It has a dry surface, except in the rainy season; "streams of considerable volume soon sinking into the porous ground, to reappear along the lower fringe of the coarse deposits."* Along the foot of the Nepál Himálaya it is covered with magnificent forests of Sál-timber; whence, in this region, the Sál-forest is used as a synonym of the Bhávar,

To the east of the Ganges, at Hardwár, "remains of an ancient Bhábar deposit become frequent and of increasing thickness; till, in the far east, at the base of the Sikim Himálaya, they stand at 1,000 feet over the actual torrents." Earlier describers regarded these deposits as an old marine formation, originating at a time when the Gangetic plain was covered by sea, but no marine remains of any kind have ever been found embedded in them. At Buxa fort, in the Bhotan Doars, it appears, from Major Godwin Austin's description, that a deposit of this character occurs at 2,400 feet above the sea.

The Bhábar occupies a zone 10 or 15 miles wide. At about that distance from the hills, the character of the country suddenly changes,† "the extreme dryness of the forest belt being succeeded by a line of swamp, clothed by a thick growth of reeds and grasses;" this is termed the Tarai. Its relation to the Bhábar may be thus explained. The small streams issuing from the hills, loaded with gravel and pebbles, deposit these coarse materials immediately on their exit. Into the porous deposit thus formed, the waters sink, until, reaching the clay bed formed by the finer sediment at some depth from the surface, they flow down it and issue in the Tarai, which lies along the margin of the Bhábar.

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* These quotations are from Mr. Medlicott's Sketch of the Geology of the North-West Provinces.

† Captain R. Strachey's Geology of the Himálaya—Quart. Journ. Geol. Soc., Lond., 1851.

The great plain that lies beyond the Tarai, although frequently spoken of as the alluvial plain of the river, is very far from being all subject to flooding. By far the greater part is at a considerable height above the rivers, and is called *Bhángar* by the cultivators, the *old alluvium* in the publications of the Geological Survey. The low flat plain, the *alluvium* proper, along the margins of the rivers, which is liable to flooding, and is called *khádar* land, is bounded against the Bhángar by steep banks, cut (at some former time) by the river. The Bhángar land is always undergoing destruction, since it is frequently cut into the river, in consequence of changes in its course, and by the small streams that carry the drainage of the higher surface into the main rivers; while it lies at too great a height to receive any addition on the surface from the flooded rivers. Large tracts of this land occur, more or less isolated, amid the alluvial plains of lower Bengal. The station of Bhágalpúr stands on such a patch of Bhángar, or old alluvium. Another larger isolated patch, known as the Mádhapúr jungle, stretches for 80 miles north of Dháka; and a ridge of the same formation, selected for the line of the Darjíling railway, runs from the banks of the Ganges at Rámpúr Boáliá up to the foot of the Sikim hills.

The Indus plain is very different from that of the Ganges. Except that part of the river bed which is deserted after each flood season, it receives no deposit from the river; and since the country is rainless or nearly so, there is but little cutting away of the surface, and, with rare exceptions, no drainage into the river. All that tract lying to the east of the Indus is a great desert, except in the immediate neighbourhood of the stream, where cultivation is rendered possible by irrigation from the river.

Of the characteristic rock formations that enter into the structure of the Himálaya, scarce one can be identified as an extension or exact representative of those met with in Peninsular India. Its geological history, as far as it is known, may be summed up by saying that, for an immense period of the earth's history, a great portion, possibly the whole of the Himálayan area, was a sea bottom on which sediment was tranquilly deposited, entombing the remains of many successive kinds of living creatures. They are all of such kinds as have lived in the sea; whereas we have seen that, in the sedimentary rocks of the Peninsula, either no organic remains have been found, or else such only as are of land or fresh water origin. The mountains north of the great snowy range, that border the valleys of the Satlej and the Spiti river to the south, are formed of a great series of stratified rocks, containing fossils of almost very great formation from the *Silucian* to the *Nummulitic* or *Lower Eocene* Epoch; rocks of the *Cretaceous* period form the summits of mountains of 20,000 feet and upwards. Clearly there then could have been no great upheaval of this mountain mass till the *Eocene* epoch. The axes of the greater ranges consist of a highly metamorphosed rock, a kind of gneiss, and this is followed by an enormous thickness of stratified rocks less metamorphosed, on which rest the fossiliferous rocks above mentioned. This is to the north of the snowy range. On the south of this axis the fossiliferous rocks are wanting, but there is a peculiar formation or series of formations, in which no trustworthy fossils have been discovered, and which are frequently much metamorphosed, that may possibly represent some portion of the fossiliferous series of Spiti, Rukshú, and Guge.

On the other hand, it is undoubted that, in times subsequent to the *Nummulitic* epoch, there have been more than one disturbance on a gigantic scale. The stratified rocks, represented in Fig. 7 as contorted and broken, are all of later age than the *Nummulitic* rocks, and those forming the Siválik hills are very much more recent. Mr. Medlicott, from whose work much of this description has been condensed, has demonstrated that a large portion of the area, now occupied by the Himálaya, was probably raised above the sea before the oldest of those deposits were formed, which now constitute the Sub-Himálaya; but there was no crushing of the rocks, and presumably no mountain chain until after the older *Eocene* or *Nummulitic* period (to which belong the oldest of the Sub-Himálayan rocks).

After the great mountain chain had been upheaved and its great valleys formed, the waste of the mountains was poured out into a sea, possibly an inland sea, at their foot. The deposits thus formed were then again upheaved and contorted, and added to the mountains, and after an interval the same thing was repeated a third time.

The formation of the great Himálayan chain has thus been the work of a very long geological period; although, as compared with some of the old mountains of the Peninsular, it is very recent. Yet, since the last great disturbance took place, contorting and upheaving the strata of the Siválik hills, a very long time indeed must have elapsed. In these hills, Dr. Falconer and Colonel Cautley found very numerous remains (chiefly bones and teeth) of a number of great animals, all of which are extinct. They include an animal called the *Chalicotherium*, which is somewhat allied to the Rhinoceros, an extinct form of Hippopotamus called the *Hexaprotodon*, a Hippotherium, a pig, two species of Mustodon (an animal closely resembling the elephant,) two kinds of elephants, a monkey allied to the Húnumán, a giraffe, a camel, an antilope, a stag, and a gigantic creature called the *Sivátherium*, a four-horned deer, far exceeding in size any existing deer. They also include many kinds of flesh-eaters and reptiles; but perhaps the most striking of these extinct creatures is the *Colossochelys*, an enormous tortoise, the shell of which alone is more than 12 feet long and eight feet across, so that the full length of the animal was probably eighteen feet, and its height seven feet. As Dr. Falconer has remarked, it may well have realized the well known Hindu fable of the tortoise that carries an elephant on its back! and he speculates on the possibility of this animal having lived on the later times, when it may have been seen by man, and have suggested the fable.

These tertiary deposits form a continuous fringe along the southern margin of the Himálaya, and, as far east as the valley of the Kosai, a distinct chain of hills enclosing the Dúns described at page 124. Opposite Sikim and Western Bhotan, this chain of hills is suppressed: the rocks in question are, for the most part, covered up and concealed by the newer deposits of the plain; and are to be seen only in the gorges cut by the rivers and hill streams. But further to the east, in Asám, they are exposed as extensively as in the Western Himálaya; and on the south of that valley they are contorted and thrown up into the great range of hills, the Burril range, which forms the boundary between British territory and the semi-independent State of Manipúr. This fact shows that this range, as well as probably a large part of the mountain system of Arakan, is of no greater antiquity than the last great movement of the Himálaya. The same remark is true of the Khási and Gáro hills; for rocks of the same age are to be met with, capping some of the hills on this plateau; and along their foot, in Silhet and Maimansing, they have been disturbed from their once horizontal position, inclined at a high angle, and dislocated by a series of fractures which run parallel with the escarpment of the hills.

For a long time previous to these disturbances, there must have been land to the north or east, and even at intervals in the region itself. Not only are these newer rocks of such a character as shows them to have been formed at no great distance from land lying in that direction; but the older sedimentary rocks, on which they rest, belonging to the *Eocene* and *Cretaceous* periods, show similar indications. On the Khási hills, rocks of both these ages contain beds of coal, which, as we know, are the remains of ancient forests; and in Upper Assam there is a large and important development of the same useful mineral, in rocks which Mr. Medlicott has shown to belong probably to the latter part of the *Cretaceous* epoch. There must, therefore, have been more than one alternation of land and sea in this region about the end of the *Cretaceous* period and the subsequent *Eocene*, to which belong the marine limestone and coal mentioned at page 46.

We will now turn our attention to the western extremity of the Himálaya, the hills of the Punjab and those along the lower course of the Indus; my notice of these will be very brief, chiefly because this region is at present less known than those already described. The plateau above the Salt-range, as well as the Hazára hills, consists of rocks of the same *tertiary* age as those which form the outer Himálaya, the Siváliks, &c. These extend up to the north foot of the Salt-range, and rest on a series of more ancient rocks, representing altogether an enormous Geological period. At the very base of all, and therefore the oldest, is the formation from which the range takes its name, a series of sandstones and clays containing beds of pure salt, the residue probably of a dried up salt lake or lakes, that existed here at a very early period of the earth's history. Following this, is a great series of formations, very similar to those noticed on a previous page, as forming the mountains around the Spiti and Satlej valleys in Tibet; containing marine fossils of *Silurian*, *Carboniferous*, and many subsequent periods in succession.

There can be little doubt that the Salt-range, with the plateau above it, was upheaved either at the time the Siválik hills were formed, or perhaps later; and it is probable that these formations would be found to extend for some distance under the lower plain, were an excavation carried to a sufficient depth.

The Sulaimán and Hála ranges are at present but little known. As far as they have been examined, they appear to be composed of upraised ridges of *tertiary* rocks similar in age and character to those of the Sub-Himálaya. There are probably older sedimentary formations exposed on the west flanks of the Sulaiman range, to judge from a remark of Dr. Fleming's; but these hills are not readily accessible to casual visitors, in consequence of the predatory and lawless character of the tribes that inhabit them. Enough is known, however, to enable us to say that these hills, like the Kachár hills at the opposite extremity of the Himálaya, are not of older date than the Siváliks. Probably all these chains, despite their difference of direction, have been upheaved at about the same Geological epoch, viz., one but little anterior to the existing state of things. The same remark is applicable to the hills of Bilúchistan to the west of Sindh, which have been visited by Major Vicary.

From the descriptions given in the two foregoing chapters, it will be seen, that both in point of physical conformation and in that of structure and geological history, the plateaux and mountains of the Peninsula are very distinct from the encircling chains. The elevation of the former is of high antiquity, that of the latter geologically recent. The former region has, for the most part, been land; the latter, for the most part, sea. The surface of the former may be compared to a palimpsest on which each succeeding age has scored its record of ridge and valley, obliterating and defacing those which preceded it. That of the latter, to an old *Sháshaná* somewhat battered and corroded indeed by time, but still exhibiting the original characters distinctly and legibly to those skilled in their decipherment.

CHAPTER XII.

THE CLIMATE OF INDIA.

By the term *climate* we mean the condition of a country in respect of its temperature, the moisture or dryness of the air, its rainfall, direction and force of the wind, the frequency and violence of storms and the like; all of which depend primarily on the quantity of heat received from the sun, and secondarily on the latitude of the place, its distance from the sea, and its elevation above the sea-level; also on the character of its surface, whether mountain or plain, whether clothed with forest, or bare of vegetation; and on the direction and height of its mountain ranges. Few countries of equal size present a greater variety of climate than India; and in this concluding chapter, it will be our business to notice some of the striking variations it exhibits, and to point out the causes on which they more immediately depend.

Although India is situated some distance to the north of the equator, (the southernmost point of Ceylon being about in N. latitude 6°), and although about half of its area lies altogether without the tropics, it is on the whole one of the hottest countries on the earth. The line that encircles the globe, indicating the zone of greatest heat, and called the equator of temperature, (to distinguish it from the equator of its figure,) runs north and south through the southern part of the Peninsula and Ceylon; and then turns off, towards Java in one direction, and towards the south coast of Arabia in the other. It is therefore an irregular line, not a true circle; and some parts of it are hotter than others. The hottest places traversed by it are situated in the north-west corner of south America, in Africa and India.

The high local temperature of India is partly to be attributed to the different behaviour of land and water when heated. Of the sun's heat that falls upon the sea surface, a large part is used up in evaporating the water, in turning it into vapour without greatly heating it; whereas, on a dry land surface, nearly the whole of it is effective in raising the temperature. Hence the land surface of India has a higher temperature on an average than the sea to the southward, although the latter actually receives more of the sun's heat. But another, and not less important reason, is the existence of the Himálayan chain; which, rising to an average height of between 18,000 and 20,000 feet, bars access to any cold winds from northern Asia; while, towards the south, India is open to the mild damp winds from the sea. If the Himálaya and Tibet were obliterated or even considerably lowered, or if, instead of running east and west, the chain ran north and south, it is probable that the climate of India would be no warmer, it might be even much colder than other parts of the earth's surface under the same latitude. If, for instance, the Himálaya occupied the place of the Western Ghats and the Aravalis, and the Gangetic plain were to stretch far away to the north where the Himálaya and the Tibetan tableland now exist, this would certainly be the case. For the south-west wind would then be arrested by the mountains, while, during the earlier months of the year, an intensely dry and cold north-east wind would blow unimpeded from the wastes of Central Asia. In a climatal, not less than in a political, point of view, then, the Himálaya is a great natural bulwark.

Different parts of India differ greatly from each other in temperature at one and the same season of year. In the months of April and May, the hottest region is situated about Central India and Rajpútána. On both the sea coasts, and for some distance inland, the heat is mitigated by the comparatively cool winds that blow from the sea towards the more highly heated land: and occasional storms also help to cool the air by the evaporation of the moisture they precipitate. In Asám and Kachár the heat is never very intense; heavy showers fall on the hills and valleys in March; and in April and May they are frequent and copious. The country is covered in great part by a luxuriant growth of forest, and in the low grounds of Silhet and Kachár large swamps exist through the year. All these circumstances tend to keep the air damp and comparatively cool; partly because there is great deal of evaporation from the water surfaces and from the leaves of the forest trees, which, as has been already explained, uses up a considerable quantity of the sun's heat; and partly because the clouds (which being condensed vapour, are more prevalent there than in a dry climate) intercept a large proportion of the sun's rays. There is another cause operating in these and other hilly countries which mitigates the heat of the valleys. I have explained in previous chapters* that the earth gives off in the night time, when the sky is clear, the heat that it has absorbed during the day from the sun; so that the air, immediately over the ground, is cooled by contact with it to a lower temperature than that which lies somewhat higher up; and I have also explained that cold air is heavier than warm air, and therefore tends to sink, for the same reason that heated air tends to rise. The air resting on the mountain slopes is therefore cooled, and becomes heavier than that which is at the same height over the valleys, and the former flows gently down, just as water would do in a similar position. This accumulates in the valleys, and often produces fogs in the night time, which are not dissipated till some hours after the sun has risen. Standing on a hill top in the early morning after a clear star-light night, the spectator frequently sees below him nothing but a sea of opaque fog, filling all the valleys around; from which the hill summits stand out clear of cloud, like islands in the ocean. In the great river valleys of the Himálaya, the quantity of cold air thus drained, as it were, off the mountain sides is such, that it flows down them in a strong current towards the plains, blowing with considerable force as a cold wind for some hours during the early morning. I shall return to this subject presently when I have to describe more particularly the winds prevalent in India.

In the rains, the distribution of temperature is very different. The Panjáb and Sindh are now the hottest parts of India, and next to them the Carnatic. While all the rest of India is cooled by the monsoon rains, these two tracts are rainless or nearly so, owing to causes which will presently be explained. On the other hand, the coolest parts, at this season, are Bengal and the west coast below the Ghats, which are precisely those where rain falls most copiously. The evaporation of the fallen rain and the shelter from the sun's rays afforded by the clouded sky are clearly the causes that produce these differences. They are most active in the latter regions; least so in the former.

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* Chapter II, page 24, and Chapter V, page 60.

Lastly, in the winter months, the Panjáb, which was the hottest region up to October, becomes the coldest in India. It is in a higher latitude than any other part of India, and therefore receives less of the sun's heat. And being far from the sea, it radiates away into space, during the night time, a larger proportion of heat than it receives from the sun in the day, and much more than the sea surface; or even than those parts of the country that border on the sea.* Moreover, at this season, it receives occasional showers; and their evaporation contributes somewhat to lower the temperature, scanty though they be. The warmest part of India is now the southern extremity of the Peninsula.

The above remarks apply more particularly to the plains; but difference of elevation also causes differences of temperature. Any one who has visited Simla, Darjiling, the Nilgiris, Mount Abú or any other hill station, is aware that the climate, more especially the temperature of these stations, is very different from that of the plains. The sun's heat, indeed, is quite as great, nay actually greater when the sky is clear; but notwithstanding this, in any shaded place, the heat of the air at no time of the year much exceeds that of the plains at the height of the cold season, and Europeans resort, therefore, to these stations, to enjoy a climate which in this respect resembles that of southern Europe. The cause of this has already been partially explained in the second chapter.† It was there stated, that a mass of air, in ascending through the free atmosphere, expands and becomes cooled; a phenomenon which can however be thoroughly understood only by those who have made some progress in the knowledge of that part of physics which treats of heat: for our present purpose, the statement of this fact must suffice. But there is another cause which much influences the temperature at these altitudes; and which I will advert to, referring the readers for a fuller explanation to some work on physics. The sun's heat, coming, as we now know, from a body at a very high temperature, passes through the air comparatively unimpeded, when the latter is free from cloud; so that, when the sun is vertically overhead, about three-fourths of it reaches the ground surface under the most favorable circumstances, the remaining fourth being used up in warming the air. The ground absorbs this heat, and at the same time the surface gives it out again, partly to the air in contact with it, partly by radiation, in nearly the same form that it received it. In *nearly* but not *quite* the same form. The heat, coming now from a dark or non-luminous body, has undergone a change which prevents it passing so freely through the atmosphere. The air, or, strictly speaking, the water vapour which exists in the air, absorbs this heat greedily; and this is more particularly the case with the lower layers of the atmosphere, which contain most vapour. Hence a further reason why the air near the ground is warmer than that at greater heights.

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* See Chapter II, pp. 24, 25.

† Pages 25 & 26.

Another kind of temperature variation, and one very important to health, is that which depends on the alternation of day and night. In a damp climate, such as Lower Bengal, and more especially Eastern Bengal, at all times of year, the difference between the afternoon temperature and that of the early morning before sunrise (the hottest and coldest periods of the day) is very much less than in the dry climate of Central India, the Panjáb and Sindh; and at any one place, it is less during the damp than during the dry season of the year. The cause is that just referred to; viz., the absorption of heat by the vapour of the atmosphere. The heat given off by the earth passes freely through *dry* air, much as light passes through glass or water; but the vapour that is in the air, though equally transparent to light, is, as has already been explained, not transparent to heat, more especially than that given out by a non-luminous body. It absorbs it and becomes warm, instead of allowing it to pass freely and escape. Hence damp air acts to the earth's surface much as a blanket does on the human body; it prevents the escape of heat, and helps to retain during the night time the heat that has been absorbed from the sun during the day.

It was explained in Chapter II that the primary cause of the winds is the unequal heating of the air by the sun; and that, in most cases, the air moves on the surface of the earth, towards the hottest places, from those which are cooler. We have very excellent illustrations of this law in the Indian monsoons. In the cold weather months, as we have just learned, the Panjáb is the coldest part of India; and accordingly the wind blows thence towards the warmer plains of Bengal, and to the seas on both sides of the Peninsula. It also blows from Upper Asám towards the Bay of Bengal and from Central India towards the coast of Bombay and the Arabian Sea;—in all these cases from a cooler to a warmer region. On the land, the course of these winds is far from uniform, for they are necessarily very much influenced by the irregularities of the surface; but at sea, the level surface of which allows them to move with equal freedom in any direction, they blow with considerable regularity from the north-east. The prevailing course of the winds in the months of November, December, and January is shown in Fig. 16 by the strong white arrow-

Fig. 16.—Wind Chart of the Winter Monsoon.

headed lines. The stream of air is hemmed in by the Himálaya on the north and by the Sulaimán and Hála ranges on the west; while the level plains of the Ganges and Indus valleys allow it a free passage. This winter wind is very gentle, and in the Panjáb and North-West Provinces, the air is very frequently quite calm. Storms never occur during this monsoon, and the sky is generally clear and of a very pale blue or grey color. On the Himálaya, at heights above 7,000 or 8,000 feet in Sikim, and at a much lower elevation in the North-Western Himálaya, the wind is generally from the south; and in the Panjáb and the upper part of the North-Western Provinces, it is not unfrequently from the east and south-east. These secondary winds are shown by the dotted arrow-headed lines on the figure. They are sometimes, but less frequently, felt in Lower Bengal, but in Cachar again they are very frequent. They bring cloudy weather, and sometimes rain. Their explanation has already been given in Chapter II, page 26, where I have termed them the *anti-monsoon*. They are portions of a current of air, coming from a great height in the atmosphere over the warm region to the south of the equator, which, becoming gradually cooled on the mountain slopes, and by giving off its heat into the free space above, descends on the plains of Upper India, and replaces the air that is flowing away to the southwards.

In the rainy season, the course of the winds is almost exactly the reverse of the above. The Panjáb is then the hottest part of India, and as shown in Fig. 17, the winds blow towards it from all quarters. In southern India the plains of the Carnatic, and in Ceylon those of the east coast, are the driest and warmest regions; and hither accordingly the winds tend, chiefly from the direction of the west coast. In Fig. 17 the arrows which represent the winds are more crowded than on Fig. 16. This is intended to indicate the greater steadiness and velocity of the south-west monsoon (so called, because, at sea, it blows almost directly from south-west). In this figure, as in the former, we may observe how the course of the currents is influenced by the Himálaya. Were this mountain chain absent, the winds from the Bay of Bengal, instead of curving round towards

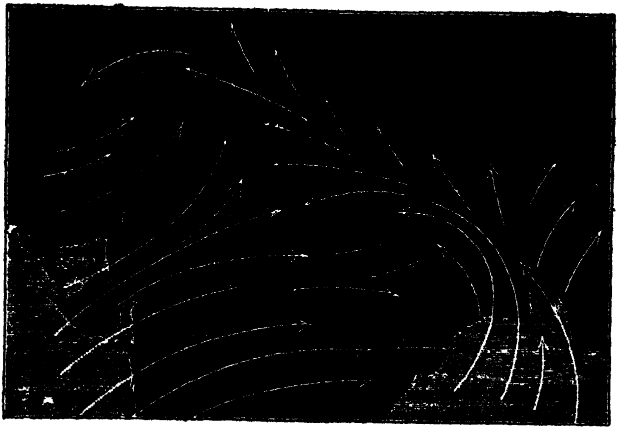

Fig. 17.—Wind Chart of the Summer Monsoon.

the north-west, would, in all probability, maintain their course in an opposite direction towards the interior of Asia; and the Upper Provinces would receive a diminished rainfall from the Arabian Sea only. But the Himálaya opposes a great barrier to any such passage, and the southern slopes of this great mountain chain and the Gangetic plain receive an increased rainfall, at the expense of Tibet and the countries further to the north.

In the south-west monsoon there must be a return current in the upper atmosphere towards the south,—another *anti-monsoon,* which probably follows somewhat the same course as that indicated by the strong arrows on Fig. 16; but it is at too great a height to be perceptible; and in order to establish its existence, we must wait till some bold aëronaut shall repeat, in India, the splendid balloon ascents of Messrs. Guy Lussac, Welsh, Glaisher and Coxwell, to whom we owe so much of our knowledge of the upper regions of the atmosphere, as they exist over western Europe..

The winds of the hot weather are different from either of the systems already described, and seem to offer a partial exception to the rule that the movement of the air is from a colder to a hotter region. At this season in Lower Bengal and Orissa, the winds blow chiefly from the sea towards the highly heated interior, and conform therefore to the general rule; but this is the case only for one or two hundred miles inland; and beyond this, hot dry westerly winds prevail during the heat of the day; dying away to a calm during the night. Yet the temperature of the North-West Provinces, Rájpútána and Nágpúr is greater than that of Lower Bengal, especially during the day time. These winds are clearly due to the heating of the air by the sun; but it is shewn by the registers of temperature at the hill stations of the North-West Provinces that the great heat is chiefly restricted to its lower stratum, which is heated partly by contact with the ground; and partly owing to the absorption of the sun's heat by the dust with which it is highly charged. It was explained in the second chapter that warm air is lighter than cold air; but this is only true supposing that the heated air is free to expand; and even then, it is lighter only in the sense that wood is said to be lighter than lead; because if two pieces of the *same size* are weighed, the former is lighter than the latter. A pound of one is of course as heavy as a pound of the other, but the pound of wood occupies more space; in other words, it is less dense. If air is heated and so pressed upon that it cannot expand freely, it remains of the same density, but presses in all directions. It presses sideways as well as upwards, and if the resistance in some lateral direction is somewhat less than that which it has to overcome in expanding upwards, it will expand in the former direction to a greater extent than in the latter. To apply these remarks to the case of the heated layer of air that covers the plains and tablelands of the Upper Provinces. The downward pressure of the superincumbent atmosphere, in the hot weather, is somewhat less in the western part of Bengal than in the Central and Upper Provinces. In expanding, some of the heated air from the latter therefore rushes in that direction, relieving the excess of pressure, and causing the hot wind. This appears to be the explanation of these winds, which are, indeed, not peculiar to India. They are felt in South Australia and even in Tasmania, where they are north-west winds, coming from the heated interior of the former continent. It is probable that the dreaded *simoom* of the Libyan and Arabian deserts, sometimes felt also in Sindh, is of a similar character, but even more intensely heated.

Another phenomenon of the hot season of Upper India is the dust-storms, which sometimes occur in the afternoon, when the lower stratum of air has been intensely heated during the morning. They frequently have the appearance of whirling columns of dust of great height, driven by a violent eddying wind; and are sometimes, but not always, followed by rain. They are due to the ascent of the heated air. At some point or other, owing to some local favouring circumstance, a part of the heated lower stratum, pressing on all sides as above described, manages to expand upwards, and to form an ascending current. The equally hot air around then rushes from all sides in towards the spot, carrying with it clouds of dust, which are borne aloft, and scattered in the upper atmosphere. The cooler air above descends and replaces that which has escaped, and the storm is followed by a marked fall in the temperature.

At times of the year when no steady moonsoon is blowing on the coast, the wind blows alternately from the sea to the land, and from the land to the sea, at different times of the day. These winds are known as sea and land breezes. The explanation usually given of them is similar to that given of the monsoons (see page 26); they are winds blowing from the cool sea towards the heated land in the afternoon and evening; and from the cooled land to the warmer sea in the early morning hours. There can be no doubt that these differences of temperature are the primary cause of these winds, but more study and observation are still required for their complete explanation.

Mountain and valley winds are also due to differences of temperature; and like land and sea breezes, they alternate during the twenty-four hours, the winds blowing towards the mountains in the day time, and down the valleys in the night. The latter have already been explained at page 137. They are produced by the downflow of air, cooled and therefore rendered more dense by contact with the mountain slopes. A very slight rise of ground is sometimes sufficient to render this effect quite perceptible to the feelings. Sometimes on a clear evening, about an hour after sunset, descending from the crest of the glacis of Fort William to the level of the maidan, a pedestrian may observe a marked change in the temperature of the air, such as may be not inappropriately described as taking a plunge into a cold air-bath. This is due to cold air flowing down the slight slope of the glacis and accumulating at its base. The mountain winds are a similar phenomenon, the action being reversed. Frequently standing on the slopes of the Himálaya or other lofty hills, wisps of clouds may be seen in the morning an hour or two after sunrise creeping up the hill-side. They are portions of ascending air currents rendered visible by their condensed vapour. This upward flow of the air, warmed by contact with the sunny hill-slopes, continues throughout the day while the sun is shining, and in the higher valleys contributes to a wind blowing up towards the passes. In the higher passes of the great snowy range, this wind blows with great violence during the afternoon, so much so indeed, that travellers speak of looking forward to its encounter with real dread. It declines towards sunset, and is followed by a calm night;

> "When all the winds are laid
> And every height comes out, and jutting peak
> And valley, and the immeasurable heavens
> Break open to their highest, and all the stars
> Shine, and the shepherd gladdens in his heart."

The distribution of rainfall in India exhibits contrasts of the most marked kind. On the one hand, the little, nearly deserted station of Chera Púnji, stands unrivalled on the whole globe, (as at present known,) for the flood-like intensity of its summer rains, which, on an average, amount to upwards of five hundred inches. On the other hand, on the plains of Bikanír and in Sindh, the whole year sometimes passes without a single drop falling on the parched surface; and between these extremes we have every conceivable intermediate gradation.

The regions of heaviest rainfall are the southern face of the Khási Hills and the Himálaya, [more especially the Duárs of Bhotan,] the Arakan coast and the west coast of the Peninsula. One circumstance is common to all of these. The face of a mountain range runs athwart the course of a wind coming direct from the ocean, and highly charged with vapour. A portion of the air is therefore driven up the face of the mountain; and, in rising, it expands, and is cooled, precipitating therefore a considerable part of its vapour. This effect is felt not only on the mountain slopes, but also in the valleys, and on the plains for some miles from their foot; for the rainfall increases steadily with increasing nearness to the hills. Thus, on approaching the the Khási and Gáro hills from the sea, in the direction of the south-west monsoon wind, the average annual fall increases as follows:—

	Distance from the hills.	Annual rainfall
Dháka	100 miles	74.5 inches.
Bogra	60 „	88.4 „
Maimansing	80 „	103.0 „
Silhet	20 „	151.3 „
Chera Púnji	0 „	521.0 „

or to take an example from the less humid climate of the Panjáb,—

	Annual rainfall.
Láhór	15.2 inches.
Ráwal Pindí	28.6 „
Hazára	43.6 „

Láhor is 100 miles from the nearest hills, and Ráwal Pindí above the Salt range, at the foot of the Hazára Hills.

On the other hand, on the *lee* side of a mountain range, that is, on the side opposite to that on which the wind blows, the rainfall is comparatively small. In ascending and crossing the mountains, the wind has lost much of its vapour, and in descending again becomes comparatively dry. This is very strikingly illustrated by places to the east of the Sahyádri range or Western Gháts. At Púna, for instance, the rainfall of the year is only 26.7 inches, while at Bombay it is 71.3, and at Mahábaleshwar, on one of the highest points of the Gháts, it amounts to 260 inches in the year.

In the Panjáb, more especially those parts at a distance from the Himálaya, the rainfall is very light, and cultivators depend in a great measure on artificial irrigation from the rivers, or from deep wells, for the success of their crops. The reason of the scantiness of the rainfall will be seen, if the reader turns to Fig. 17, which represents the direction of the winds in the south-west monsoon. The only winds that bring rain are those which come from the Arabian Sea and the Bay of Bengal. But in both cases these winds have to traverse an enormous extent of country before they reach the Panjáb; and that which comes from the Arabian sea must pass in its course over two great ranges of hills. They have, therefore, lost most of their vapour before they arrive at the Panjáb; and there, the excessive heat* prevents the condensation of much of the residual vapour. As a consequence, during the four months from June to September, less than 10 inches of rain, on an average, falls at Láhor; and at Múltán less than 4 inches in the same period.

In Sindh and the Bikanír desert, easterly winds are more rare than in the Panjáb. The same causes which, in the northern part of the Indus plain, draw in air from the east, in the southern part, cause an inflow from the west. But Bilúchistán, which lies in that direction, is an exceedingly arid country; and the westerly winds are in consequence hot and devoid of moisture. Hence the rainless character of Sindh.

The summer rains of the Panjáb are, as we have seen, very light; but in December and the early months of the year, more rain falls there, and in the upper part of the North-Western Provinces, than in any other part of India, except on the Himálaya. It has been explained already that this is owing to the descent of the anti-monsoon current, (which brings vapour from the far south,) blowing in the upper atmosphere, and descending on the Himálaya and the Panjáb.

In Madras again, and the Carnatic generally, as well as the east coast of Ceylon, the chief rains fall in October, November, and December, that is, at the close of the south-west monsoon. It has often been stated that these rains are brought by the north-east monsoon, but, strictly speaking, such is not the case. For six weeks or two months after a

See page, 137.

north-east wind has begun to blow in the north of the Bay, southerly winds still prevail in the south, and these curve round and blow from the east towards the Carnatic, which, having received little or no rain up to that time, is now the hottest part of India. It is these winds that bring the rains of the Carnatic. Later on, when the north-east monsoon prevails down to lower latitudes, fine, dry weather is prevalent on the plains of the Carnatic as elsewhere.

It is at this season more especially, but also at the opposite change of monsoons in May, that those destructive storms called *cyclones* are most prevalent. In these storms, the winds blow with fearful violence in a vortex, moving spirally inwards towards a central region, where there is a complete calm. This central calm area is from 8 to 15 miles across; and immediately around it, the winds blow with their greatest violence. All the phenomena of these storms show that there must be an ascending current of air around, and partly over the calm region.

The great storms of this kind, to which the term *cyclone* is usually restricted, always originate over the sea; and in the Bay of Bengal, after two or three days, they travel forwards in a direction, most commonly between north and west, towards the land; their violence generally increasing as they advance. The vortex of the storm, where the winds move nearly in a circle, is between 100 and 200 miles across; and the stormy weather prevails all around, except on the left of the path followed by the vortex. The revolution of the winds in these storms, in the Bay of Bengal, as everywhere in the northern hemisphere, is always in the same direction, *viz.*, opposite to that in which the hands of a clock move; or from east through north and west to south. As a consequence of this revolution, if a place lies directly on the mid-track of the storm, which we will suppose to be advancing from due south, the wind blows at first from north-east, and then changes gradually to E.N.E.; in which quarter it continues, increasing steadily in force until the central calm reaches the place. In the course of a minute or two, the hurricane violence of the wind is then quelled. A dead calm follows, and lasts from a few minutes to (in certain cases) nearly an hour. Then, almost without warning, the hurricane sets in once more, but this time from the westward, or from the quarter almost exactly opposite to that of the first half of the storm. Hence it blows for an hour or two, (sometimes much longer) with a gradually diminishing force, and finally veers to south-west, when the storm is over.

At any place to right or left of the central track, no calm is felt. If the place lies within the right hand half of the storm, the wind begins from north-east, or between that direction and east; and then veers as the storm progresses, changing to east, south-east, south, and finally south-west. If on the left of the storm, the change takes place in the opposite direction, *viz.*, to north, north-west, west, and finally south-west. These directions are those generally observed in Bengal, where the storms most frequently come from the south. They are somewhat different if the storm approaches from the south-east, as is usually the case in Orissa, or from the east, as in Madras; but the opposite veering of the wind, on opposite sides of the centre, is the same as that described. It is, therefore, always possible to tell in which direction the storm is passing, (whether the centre is to the east or west, &c., of the observer) by the direction in which the wind veers.

When a cyclone reaches the coast, it is generally accompanied by a rise of the sea above the ordinary level, termed the *storm-wave;* and should this enter an estuary, such as that of the Húghli, it sweeps over the low lands around, flooding them and producing even greater devastation than the wind. On the 5th October, 1864, a very fierce cyclone passed over Calcutta, the track of the centre being a few miles to the west of the city. The destruction caused among the shipping was very great: 31 ships and steamers, nine of which were over 1,000 tons burden, were wrecked in the river; all the ships in port were driven from their moorings, and one of the P. O. Company's large mail steamers was landed high and dry on Shalimár Point, opposite Calcutta. For many weeks afterwards, the banks of the river were strewn thickly with wrecked boats and cargo. But great as was the destruction caused by the wind, it was far surpassed by the devastation of the storm-wave, which rolled in over the low lying tracts of Medinapúr and the

24-Parganas; in some places, 20 feet in depth, sweeping everything before it. Upwards of 48,000 people were drowned in this terrible flood, and in the following months 25,000 more fell victims to the fever and starvation which were the after-effects of the catastrophe.

Tornados, or whirlwinds, resemble cyclones in the vorticose motion and violence of the wind, but are much smaller, and do not generally exceed one or two miles in diameter. They originate over the heated land in the hot weather months, and, within a limited area, are very destructive to houses, trees, &c. The dust storms of Upper India, described at page 144, are a kind of tornado. *North-westers* is the name given to the thunder storms that occur in the hot weather, generally in the afternoon or evening, and at Calcutta, most frequently approach from the north-west quarter, whence their name. They are preceded by violent gusts of cold wind which bring up clouds of dust, while a sheet of dark cloud, with a hard even outline, advances rapidly over the sky. The wind is followed after some minutes by heavy rain accompanied by vivid lightning and loud thunder. These storms sometimes usher in a day or two of rain, but most frequently an hour or less suffices for their exhaustion; after which the sky clears, and a cool atmosphere is ensued for the night and following day.

CONCLUSION.

We have now completed our survey of those simple and more striking phenomena which we had in view at the outset. It has not been my object, nor would it have been possible, in a little elementary treatise such as the present, to do more than glance at the several objects of interest that have successively presented themselves to our notice, and to give a brief commentary on their nature and relative importance in the economy of the world: but enough has, I think, been said, to give my readers some idea of the richness of the field we have traversed; not to speak of those that lie beyond and over the borders of which we have not ventured. Physical Geography is not a single science, but draws its materials from many distinct sources. From the Chemist it borrows the knowledge of the simple forms of matter, the *chemical elements*, of which every material object is made up, and of the laws according to which these combine together and separate; and from the Mineralogist it derives the knowledge of the appearance and nature of the natural compounds that form stones and rocks, and the conditions under which they are met with in nature. From the Physicist it learns how matter is affected by heat, light, and electricity; from the Mechanist, the laws of motion and rest; and from the Astronomer, how our earth, in obedience to those laws, is affected by the other orbs of space. From the Geologist it takes the ascertained facts of the past history of the earth, furnishing him in return with the key by which he is enabled to read that history in the stony masses now exposed on its surface. From the Zoologist, Botanist and Palæontologist, the description, structure and habits of the animals and plants that now live, or that have lived in distant ages and have long since passed away; and finally the Ethnologist furnishes that knowledge of the various races of men and their mutual relationship, as indicated by their physical peculiarities, their habits, superstitions, and languages, that enables the

Physical Geographer to study man in his relation to other animals, and the manner in which he influences, and is influenced by, the geographical circumstances of his position. While these cultivators of special branches of science concern themselves with some one selected class of objects, or of effects, it is the business of the Physical Geographer to regard nature as a whole; to take as the objects of his study, the earth and its inhabitants in all the varied and complex phases that present themselves to his observation, and to seek their explanation in the facts furnished to him from the storehouses of the special sciences. But this he cannot do, unless he has himself gained a considerable acquaintance with the matter and methods of those sciences, or at least with such of them as have an important bearing on that part of Physical Geography to which his attention is given. For the *thorough* comprehension of the subjects discussed in the foregoing pages, some knowledge of Chemistry, Mechanics and Physics is indispensable; and to these subjects, before all others, the student's attention should be turned.

On the other hand, Physical Geography itself furnishes the key to which the Geologist, the Naturalist and the Historian must have recourse, for the explanation of much that concerns the objects of their special study. The first interprets the relics of the past, by observing the changes that are now in progress around him, and noting their permanent effects. The second has recourse to the facts furnished by Physical Geography, to explain the distribution of animals and plants, and to determine what circumstances are favorable and what are adverse to their extension; and the Historian discovers, in the fertile arable plains of great rivers, the conditions essential to the development of early civilizations, and at a later time the lure that has attracted the inroads of poor and hardy races, when ease and plenty have enfeebled the earlier settlers and rendered them an easy prey. In fact, many of the more important facts of the history of nations, most of the more salient peculiarities of national character, are traceable, in a large measure, either directly or indirectly, to the physical circumstances of their position.

And the science has a present and future, not less than a retrospective interest. In all conditions of life we seek to turn to our convenience and advantage, the spontaneous gifts and conditions of nature; and our power to do this, to utilize her resources, to abstain from wasting them, and to fortify ourselves against those adverse occurrences that we cannot prevent or control, will be in exact proportion to our knowledge of natural laws. The History of Engineering abounds in instances of the successful controlling of powerful natural agents, to accomplish important ends. In Tuscany, the deadly marshes of the Maremme and the Val de Chiana have been converted into salubrious and fertile plains, by turning on them and confining the silt-laden waters of local streams in such manner that the surface has been continuously raised by their sediment. The Mahánadi river, which, for some years prior to 1857, was gradually deserting that branch which flows north of Katak, and by unduly filling the southern channel, threatened the safety of the town, was forced back into the former, by a small spur of stones and tree trunks so laid as to determine the formation of a sand bank by the river itself, which maintained the current in the required direction. Any engineer of experience would be able to cite numerous similar examples.

On the other hand, the disastrous consequences of ignorance have already been illustrated in the case of reckless forest clearings, by which, in some cases, large tracts have been rendered uninhabitable, and many a useful perennial stream has been brought into the alternating conditions of a dried up channel and a devastating torrent.

And lastly, when control is impossible, a knowledge of nature will frequently enable us to avoid impending misfortune; of this an excellent illustration is furnished by the discovery of the Cyclonic motion of the winds in great hurricanes, by Reid and Redfield, together with that knowledge of their prevailing tracks, which was afterwards extended to Eastern Seas by the labours of Piddington, Thom, and latterly Meldrum. Furnished with this knowledge, and warned by his barometer, the seaman may frequently escape the threatening gale, and even take advantage of the strong winds that blow in the wake of the Cyclone, to help him forward on his course.

GLOSSARY

OF TECHNICAL TERMS USED IN THIS WORK.

Abbreviations:—Gr. Greek; Fr. French; Ital. Italian; Swed. Swedish; Lat. Latin Ar. Arabic; Germ. German; Sans. Sanscrit; Hind. Hindee; Span. Spanish.

Aerial—[Gr. *aër*, air.] Relating to the air.

Aeronaut—[Gr. *aër*, air; *nautes*, a sailor.] One who travels through the air, as in a balloon.

Affluent—[Lat. *ad*, to; *fluo*, I flow.] A stream or river which unites with another, (the latter being regarded as the principal stream,) is termed its affluent or tributary.

Alluvium—[Lat. *alluvius*, added by the wash of water.] A term applied to land formed by rivers during the overflow of their banks. See page 88.

Amphibian—[Gr. *amphi*, both; *bios*, life.] Living both on land and in water. The Zoological name of a large class of animals, of which the common frog and toad are familiar examples. In the earlier period of their life they live in the water, and have breathing organs like those of fishes, but at a later period they acquire lungs and breathe air.

Antarctic—[Gr. *anti*, opposite to; *arktos*, the bear, *i.e.*, the northern constellation so called.] The designation of the earth's southern pole, and the region around it.

Antipodes—[Gr. *anti*, opposite to; *podes*, the feet.] That part of the earth's opposite surface which would be intersected by a line drawn from a given place through the earth's centre and prolonged to the further side, is called the antipodes of that place.

Anti-trade—See Trade Winds.

Aqueous—[Lat. *aqua*, water.] A term applied by Geologists to all rocks that have been formed in water. See page 46.

Arable Land—[Lat. *aro*, I plough.] Land fitted for ploughing, *i.e.*, for field cultivation.

Arctic—[Gr. *arktos*, a bear.] A term applied to the earth's north pole and the region around it, since the *pole-star*, towards which the north pole of the earth's axis points is in the constellation called the 'Great Bear.'

Atmosphere—[Gr. *atmos*, vapour; *sphaira*, a sphere or ball.] That mixture of gases and vapours which surrounds the earth, as well as many other bodies of the solar system, the stars, &c. See page 19.

ATOL—[Malay. *atol.*] A name given by their inhabitants to certain low ring-shaped islands enclosing a lagoon, and formed entirely of the remains of the coral animal. The Maldives and Laccadives consist exclusively of *atols.*

AXIS—[Lat. *axis*, an axle.] In Geography, that line through the centre of the earth, passing from the north to the south pole, around which the earth revolves.

BAR of a river; the shoal which runs across certain rivers where they enter the sea, obstructing their entrance. See page 98.

BARRIER-REEF—A reef (see REEF), formed by the growth of coral, which partly or completely encircles certain islands, from which however the reef is separated by a navigable channel, sometimes many miles broad.

BASIN of a river. See DRAINAGE BASIN.

BAY—A portion of the sea that occupies a recess or retreating curve of a coast line between two capes or headlands. Ex.: The Bay of Bengal.

BEACH—The layer of rounded water-worn pebbles, which, on certain rocky coasts, accumulates along the sea-shore.

BED—In Geology, the term applied to a single definite layer of a sedimentary rock. It may vary in thickness from a few inches to a hundred feet or more. A *Bedded* rock is one which consists of definite layers or *beds.*

BED of a river. The bottom of the river channel.

BORE—In Physical Geography, a term applied to the high wave formed by the advancing flood tide in certain estuaries, where the tidal wave is retarded by the shallowness of the channel, and raised by the convergence of the shores. See page 39.

BOTANY—[Gr. *botane*, grass.] The name of that branch of science which treats of the structure, habits, and classification of plants.

BOULDER—In Geology, an isolated block of hard rock, which either rests on the surface or is embedded in clay, gravel, &c., and has been transported from a distance to its actual position, generally by the agency of ice.

BRACKISH—A term applied to water, distinctly salt to the taste, but less so than sea-water.

BREAKER—Sea waves, which being impeded by the shallowness of the water, or arrested by an opposing reef or rock, break up in masses of foam.

CARBON—[Lat. *carbo*, charcoal.] The name of one of the chemical elements or simple substances. The diamond is one form of carbon, plumbago or black lead another, and pure charcoal a third, since these substances are chemically the same.

CARBONIC ACID—The name commonly given to a kind of gas which may be prepared by burning charcoal in air. It is also given out from the lungs in breathing, and always exists in the air in the proportion of about four parts in ten thousand of air. In recent chemical works the name Carbon dioxide is generally given to this gas, the term Carbonic acid being reserved for a solution of it in water. Air that contains a large quantity of the gas is poisonous if breathed.

Cascade—[Ital. *cascare*, to fall.] A synonym for a waterfall.

Cataract—[Gr. *Katarraktes*, a waterfall.] Usually applied to waterfalls of large volume.

Catchment Basin. See **Drainage Basin**; also p. 88.

Chemistry.—[deriv. uncertain, probably Gr. *Chymos*, juice.] A branch of modern Science which treats of the ultimate composition of matter, and the laws according to which simple substances combine to form definite compounds and the reverse. At the present time 63 subtances are known, which cannot be resolved into anything simpler, and are therefore called *elements.* Forty-five of these are metals, and the remainder, including such bodies as sulphur, carbon, oxygen and nitrogen, are non-metals or *metaloids.*

Char—Pronounced and improperly written *chur.* [Hind. *char*, a shoal or sand bank in a river.] The term commonly applied to the banks of sand and silt, left dry on the subsidence of rivers after the flood season, and frequently brought under cultivation during the dry weather.

Climate—[Gr. *Klima*, the inclination of the earth's surface to the sun.] For the modern meaning of the term, see page 135.

Condensation—[Lat. *condenso*, I make dense.] In Physics, the conversion of a vapour or gas into a fluid, effected by cold or pressure, or both together.

Continent—[Lat. *continens*, holding together.] The principal masses of land on the earth's surface.

Contortion—[Lat. *contortio*, an intertwining.] In Geology, a term used in describing bedded rocks which have been bent up in folds as represented in Figs. 7 and 10, pp. 68 and 70.

Coral—The stony skeletons of a class of animals termed *Zoophytes.* Zoophytes live in the sea attached to rocks, and in many cases grow by a process of budding and fissure, whereby a branching organism is produced. In Tropical seas, numerous islands and reefs are formed exclusively of the stony *debris* of the coral. See **Atol** and **Barrier-reef.**

Crater—[Lat. *crater*, a bowl.] The funnel-shaped cavity at the summit of a volcanic cone, from the bottom of which a pipe-like orifice communicates with the interior of the earth, and is the channel through which gases, ash and other stony matter are ejected.

Crust of the Earth—The external shell of the earth, which is certainly solid, whatever may be the condition of the interior. At present the use of the term does not necessarily imply the fluidity of the interior, although such was the original assumption.

Crystals—[Gr. *Krystallos*, ice.] Those definite geometric forms, which the majority of the elements and definite chemical compounds assume or tend to assume, when they pass from the fluid to the solid state; and by which each element or compound is characterized. Thus common salt and many of the metals assume, under such circumstances, the form either of the cube or the octohedron. Rock crystal always occurs in the form of a hexagonal prism, &c. A confused mass of crystals, none of which have had room to develope into regular forms is said to be CRYSTALLINE. Such is frequently the case with the minerals forming the crystalline rocks. The classification, geometric properties, structure, and physical peculiarities of Crystals constitute a distinct branch of Natural History, termed Crystallography.

CYCLONE—[Gr. *Kyklos*, a circle.] Violent storms, in which the winds blow in a spiral direction, around a central calm region. For a fuller notice see p. 148. In the China Seas, where they are very prevalent in the months of August and September more especially, they are called *Typhoons*.

DEBRIS—[Fr. *debris*, remains, ruins.] This is scarcely a technical term. The fragments separated by frost and the action of the atmosphere from a parent rock are conveniently spoken of as its debris. When such fragments accumulate, forming a pile at the foot of a hill or escarpment, they form a TALUS.

DEGREE—In Geometry, the circumference of the circle is divided into 360 parts, each of which is termed an arc of one degree. The term *degree* also expresses the measurement of the angle included by the two radii that subtend one of these parts. In Geography, the latitude of a place is the angle included by two lines drawn from the earth's centre, one of which intersects the place, and the other the point of the equator nearest to it. The longitude is the angle included by two lines drawn from the nearest point of the earth's axis, one of which intersects the place, the other the point of the earth's surface in the same latitude, on a meridian [see MERIDIAN] passing through some standard observatory. In English maps, longitude is counted from the meridian of the observatory of Greenwich; in French maps from that of Paris; in German maps frequently from Ferro. Latitude and longitude, being both the measurement of an angle, are expressed in degrees.

DELTA—See page 95.

DENSITY—[Lat. *densus*, close, crowded.] In Physics, the density of a body is measured by the weight of a standard unit volume, *e.g.*, a cubic inch, or a cubic centimeter of the substance; and is expressed by comparing this weight with that of an equal volume of some standard substance; which, for solids and fluids, is usually pure water taken at the standard temperature of 4° on the Centigrade thermometer. The number that expresses this relation when the substance has the temperature of melting ice, is called the *specific density* or *specific gravity* of the body. Thus a cubic inch of lead, at the freezing point, weighs 113 times as much as a cubic inch of pure water at the temperature of 4° of the Centigrade thermometer. This number therefore expresses the specific gravity of the metal. The density of gases is compared in like manner with that either of hydrogen or air at the freezing point. Most bodies expand when heated and occupy more space, while their weight remains unaltered. Their density therefore decreases, as their temperature rises. But water below the temperature of 4° Centigrade is an exception to the rule. It is most dense at this temperature. Hence this has been taken as the standard of comparison.

DENUDATION—[Lat. *denudo*, I lay bare.] In Geology, a term applied to the process of removal of the superficial parts of the land, by the agency of the atmosphere and water. For a description of those processes, see page 33 and Chapters VII, VIII and IX.

DESERT—[Lat. *desertus*, past participle of *desero*, I abandon.] A tract of country uninhabitable by man; generally owing to the absence of water.

DETRITUS—[Lat. *detritus*, past participle of *detero*, I wear away.] In Geology, the material worn away from the surface of the land by rivers, &c.

DEW—The water that condenses from the atmosphere on a surface colder than the air. See page 23.

DISINTEGRATION—[*Dis*, prefix implying separation, and *integrate* from Lat. *integro*, I make whole.] In Geology, the process by which solid rocks become decomposed into clay, sand, &c. [see page 103] or are broken up, as by frost [see page 80].

DRAINAGE BASIN OR DRAINAGE AREA—The whole of the land surface which is drained by one river and its tributaries is called its *drainage basin*.

DUNES—[Fr. *dune*, a down.] In English Geography, applied to those tracts of bare sand, blown up by the wind into ridges or sand hills, which form on certain sea coasts and on the margin of rivers with broad sandy beds.

DYKE—An artificial embankment for the purpose of restraining a body of water.

EARTHQUAKE—A shaking or vibration of the earth, produced by an explosion or disturbance of that character, deep below the surface. From the [proper] use of the term *wave* in describing this motion, it is frequently inferred, that in an earthquake, a visible wave rolls along the surface of the earth. This is not the case. The earthquake wave is of the same kind as that which conveys sound through the air, and consists of an increase and decrease of density rapidly alternating in parallel sections of the rocks. This necessarily produces a swaying, oscillating movement in houses, trees and other objects on the surface.

ELECTRICITY—[Gr. *electron*, amber.] The name of a form of energy, [see that word,] manifested when dry glass, sulphur, and resinous substances, especially amber, are rubbed; in consequence of which they acquire the power of attracting light bodies, and afterwards repelling them. Lightning is a familiar electric phenomenon. Electricity can be communicated through metallic wires, properly protected, with extreme rapidity to distant places; [in Professor Wheatstone's experiments 288,000 miles in a second of time;] and this property is utilized in the electric telegraph. The laws and phenomena of electrical action constitute an important section of PHYSICS.

ENERGY—[Gr. *energeia*, efficacy.] A term used in modern Physics to express the capacity for doing work against resistance. Heavy bodies in motion; or at rest, in a position such that they can be set in motion without expending work upon them; heat, light, electricity, &c., are all forms of energy; and one can be converted into the other; in which case a constant definite quantity of one is obtained by the expenditure of a given fixed quantity of the other. Thus a weight of 772lbs. falling through one foot, when the motion is arrested, will generate the heat required to warm the same weight of water one degree of Fahrenheit's thermometer, and 1 lb. of pure charcoal completely burned in air generates heat enough to warm 14,544lbs. of water one degree. Conversely, the former quantity of heat, expended by a *perfect* steam engine, would raise 772lbs. one foot high; and to separate the pound of charcoal again from the gas which it produces in burning, would require 14,544 times that amount of work or its equivalent in electricity or some other form of Energy. The total quantity of Energy in the universe is therefore constant, while its forms are ever varying.

EQUATOR OR EQUINOCTIAL LINE—[Lat. *æquator*, that which divides equally]. A circle drawn round the earth, midway between the two poles, and dividing the surface into two equal hemispheres, the northern and the southern. At places on the equator, the days and nights are of exactly the same length (12 hours each) all the year round. Hence the equator also termed the equinoctial [from Lat. *nox. noctis*, night] line.

ERUPTION—[Lat. *eruptio*, an outbreak.] In Physical Geography the active condition of a volcano. See page 62.

ESCARPMENT—[Fr. *escarpe*, steep.] The precipitous or steeply inclined face of a cliff, or the abrupt slope surrounding a tableland.

ESTUARY—[Lat. *æstus*, the tides.] An arm of the sea, or the lower part of a river communicating with the sea, up which the tidal waves pass.

ETHNOLOGY—[Gr. *ethnos*, a nation or tribe; *logos*, a discourse.] That branch of science that deals with the races of man, their physical and mental characteristics, their variations of structure, habits, beliefs, languages, and mutual relationship and descent.

EVAPORATION—[Lat. *evaporo*, I disperse in vapour.] The process by which a fluid is converted into a vapour, as water into steam. In Physics the term is sometimes restricted to that quiet passage of water or other fluid into vapour, which takes place at temperatures below that at which the fluid boils.

EXOTIC—[Gr. *exótikos*, foreign.] A term applied to the natural productions of a foreign land. Especially applied to plants and animals that have been introduced from foreign countries.

Fathom—A measure of six English feet, or two yards, used in measuring depths of water.

Fauna—The whole group of the animals native to a country, or that lived at a particular geological epoch in a given country.

Flora—[Lat. *flos*, a flower.] The whole group of the plants native to a country, or found fossil in a particular geological formation.

Fluviatile—[Lat. *fluviatilis*, pertaining to rivers.] In Geology, applied to a deposit formed by a river, such as the delta. In Zoology to animals and plants that live in rivers.

Foliation—[Lat. *folium*, a leaf.] In Geology, applied to that arrangement of the minerals in thin parallel layers, which characterizes Gneiss and other metamorphosed rocks. Sometimes this arrangement coincides with the original stratification of the rock; in other cases foliation is set up in a different set of planes, developed by pressure, during metamorphism.

Formation—In Geology "any assemblage of rocks which have some character in common, whether of origin, age or composition." [Lyell's Elements.] With respect to age, the following is the order of the great formations, each of which is distinguishable from that which precedes and follows it, by certain marked peculiarities of the fossil fauna. [See that term.] As the Geology of the less familiar and accessible parts of the world becomes better known, formations are discovered which tend to link together these several formations in a continuous series: but, nevertheless, it is probable, that these familiar divisions will be retained as convenient standards of reference, perhaps with interpolations. The following list is taken from Sir Chas. Lyell's Elements of Geology, and enumerates the formations in descending order:—

Post Tertiary		
Pliocene ...	Tertiary or Cainozoic	Neozoic Formations.
Miocene ...		
Eocene ...		
Cretaceous ...	Secondary or Mesozoic	
Jurassic ...		
Triassic ...		
Permian ...	Palaeozoic.	
Carboniferous ...		
Devonian ...		
Silurian ...		
Cambrian ...		
Laurentian ...		

The Nummulitic formation referred to at page 130 is an important member of the Eocene.

Fossil—[Lat. *fossus*, past participle of *fodio*, I dig.] A term formerly applied to all mineral products and curiosities. In modern science the term is restricted to any animal or vegetable body, or the traces of the existence of any such body, which have been buried in the earth by natural causes. Thus shells, bones, or even mere impressions, such as footprints, that are met with embedded in the rocks, are properly termed 'fossils.'

FRESHET—The sudden rise of a small stream or river, produced by a heavy fall of rain, or the rapid melting of snow.

GAS—Any substance, which, at ordinary temperatures, is in an aëriform or air-like condition. All the known gases, except six, have been condensed [see CONDENSATION] by great cold and pressure, acting alone or together.

GENUS—[Lat. *genus*, a race or stock.] In Zoology the term applied to a collection of species, [see that term,] which resemble each other in a large number of important points; the first degree in the classification of kinds. Thus the horse, the domestic ass, the hemionus, zebra, and quagga, all being horse-like animals belong to the same genus. So also the dog, jackal, fox, and wolf are species of the genus *canis*, or dog. The limits of a genus are to some extent a matter of opinion and convenience; some naturalists making these groups more comprehensive than others.

GEOLOGY—[Gr. *Ge*, the earth; *logos* a discourse.] That branch of science which treats of the past history of the earth, the classification and structure of rocks, and the causes by which they have been produced.

GHAT—[Hind. *ghát*, a landing place, ford or pass.] Originally applied, by Indian Geographers, to the passes in the mountain ranges that run parallel with the two coasts of the peninsular, and which have to be traversed in order to reach the interior from the coast; the term has been transferred to the ranges themselves.

GLACIER—[Fr. *glace*, ice, whence *glaciér*, a river of ice.] See page 79.

GNEISS—[Germ. *Gneiss.*] A term originally used by German miners, and adopted by Werner, as the Geological name of a kind of foliated [see that term] metamorphic rock, which, in its characteristic form, consists essentially of three minerals, quartz, felspar and mica.

GORGE—A narrow pass or river channel with precipitous rocky walls.

GRANITE—[Lat *Granum*, a grain.] A rock, the most characteristic variety of which consists of the same three minerals as the above; but varying much in composition. For further details, see page 50.

GRAVEL—A mixture of sand and small pebbles in a loose incoherent condition.

GRAVITATION OR GRAVITY—[Lat. *gravis*, heavy.] The pulling force which every particle of matter, whether solid, liquid or gaseous, exerts on every other particle, at all distances. See page 12.

HAIL—Fragments of ice, formed in the clouds, and falling like rain. These fragments, termed *hail-stones*, are sometimes as large as a pigeon's egg, and are the very destructive to trees, crops, &c. Very much larger masses have been known to fall in hail-storms; but in such cases they consist of a number of hail-stones frozen together.

HOARFROST—Dew which is deposited in a frozen state.

HORIZON—[Gr. *horizo*, I limit.] See pages 9 and 10.

HURRICANE—[Span. *huracan*, from an American-Indian word probably in imitation of the rushing of the wind.] A storm of extreme violence. Cyclones are frequently spoken of as hurricanes.

ICEBERG—[Germ., *berg*, a rock]. See page 82.

IGNEOUS—[Lat. *ignis*, fire.] In Geology, applied to rocks solidified from a fluid condition into which they have been brought by the agency of the internal heat of the earth.

INTERTROPICAL — The region north and south of the equator, bounded by the tropics of Capricorn and Cancer. These are two circles parallel to the equator, in about 23½° latatude. All places situated on the northern tropic (Capricorn) have the sun vertical at noon on the 21st June, and places on the southern tropic on the 21st December.

JHIL—[Hind. *jhil*, a shallow lake or morass.]

KHALL—[Hind. *khál*, a creek.]

LAGOON—A shallow lake, generally brackish or saline. See page 108.

LANDSLIP—A portion of a hill-side or cliff, that being loosen by rain or springs, is detached and slides down.

LATITUDE—[Lat. *latus*, broad; *latitudo*, breadth.] In Geography, the angular distance of a place to north or south of the equator. See DEGREE.

LAVA—[Ital. *lava.*] The molten rock that flows from a Volcano in eruption. See page 62.

LIME—Tho white substance used in the preparation of mortar, cement, &c., and eaten with pân. It is a compound of a metal called *calcium*, with *oxygen*.

LIMESTONE—A kind of rock consisting of the metal calcium combined with oxygen and carbon. When burnt, it yields lime.

LOAM—Earth consisting of a mixture of clay, sand, and decayed vegetable matter.

MAGNESIA—A white powder consisting of a compound of the metal *magnesium* with oxygen. It is one of the constituents of Epsom salts, and also of the salts dissolved in sea-water.

MAGNETISM—The property, possessed by a kind of mineral called the *loadstone*, of attracting iron. The same property may be imparted to steel bars, and temporarily to soft iron. A steel bar thus treated is said to be magnetized, and if suspended in a horizontal position by a thread, so that it is free to place itself in any direction, it comes to rest pointing north and south, or nearly so.

MARINE—[Lat. *marinus* from *mare*, the sea.] Pertaining to the sea.

MERIDIAN—[Lat. *meridies*, noon.] In Astronomy, an imaginary plane passing through a given place and coincident with the earth's axis. At noon the sun is on the meridian.

METAMORPHISM—[Gr. *meta*, prefix implying change, *morphe* form.] The changes which sedimentary rocks undergo, under the influence of pressure, heat, and heated water, whereby they are altered in appearance and structure, frequently becoming crystalline. The term 'metamorphic rocks' is restricted to those which have undergone this extreme degree of alteration.

MICA—[Lat. *mico*, I glitter.] The name of a kind of mineral, which splits readily into thin transparent sheets, which, when of sufficient size, are frequently used as a substitute for glass; also in the state of powder, as a decorative material, producing a sparkling effect, whence the name.

MINERALOGY—The branch of Natural History that deals with stones, and all natural compounds found by chemical action, without the agency of life.

MIRAGE—[Fr. *mirage*, looming.] A kind of ocular deception. The appearance of sheets of water on dry heated plains, due to the total reflection of light from the surface of a heated stratum of air.

MOLLUSCA—[Lat. *molluscus*, a soft nut with a thin shell.] The Zoological name of a section of the Animal Kingdon comprising snails, slugs, oysters, cuttle fishes, &c., all of which have soft bodies enclosed in a membrane termed the *mantle*, which in some cases secretes a stony or horny shell.

MONSOON—[Ar. *mausim*, a season.] Winds which blow alternately in opposite directions, at opposite seasons of the year. See pages 26 and 140.

MORAINE—[Fr. *moraine*.] The ridge of rock blocks formed at the lower end of a glacier. Those at the sides are termed lateral moraines; that at the end, the terminal moraine. See page 80.

NALA—[Hind *nala*, a rivulet or brook.] Frequently written *nullah*.

NEAP-TIDES—See page 37.

NEVE—[Fr. *névé*.] The beds of snow in which glaciers originate. See page 79.

NITROGEN—[Gr. *nitron*, nitre, saltpetre; *gen* root of *gennao*, I generate.] The name of a gas; a chemical element which constitutes four-fifths of the atmosphere, and in composition with other elements forms nitric acid, nitre, &c.

NORTH-WESTER—See page 150.

ORBIT—[Lat. *orbita*, a wheel track.] In Astronomy the line described by a planet around the sun, or by the moons around their respective planets.

OUTCROP—In Geology, that part of a bed of rock, a mineral vein or other formation, that appears at the surface of the ground.

OXYGEN—[Gr. *oxys*, sharp, acid, and *gen* the root of *gennao*, I generate.] The name of a gas discovered by Priestly. One of the chemical elements, which constitutes one-fifth of the atmosphere, and enters into composition of the most acids. Hence the name given to it by Lavoisier.

PALÆONTOLOGY—[Gr. *palaios*, ancient; *on*, existence; *logos*, discourse.] A branch of Natural Science that treats of extinct animals and plants, whose remains are preserved as fossils. [See that term.]

Pass—A gap or dip in a mountain ridge or range, by which travellers can pass at the lowest level from one side to the other.

Peat—Decayed vegetable matter, which accumulates in certain swampy places, sometimes to a thickness of many feet. It is chiefly formed by a species of moss. The same term is given to beds of decayed vegetable matter met with in recent formations, as mentioned at page 44.

Peninsula—[Lat. *pene*, almost; *insula*, an island.] The term is applied to any tract of land surrounded on three sides or more by water, but connected with a continent or other large land area.

Permeable—[Lat. *permeo*, I pass through.] A term applied by Geologists to all rocks through which water can pass.

Phase—[Gr. *phasis*, something seen.] In Astronomy, applied to the appearances successively presented by the moon, during a lunation.

Phenomenon, plural **Phenomena**—[Gr. *phainomai*, I appear.] In Science, any natural appearance. Anything presented to the senses by observation or experiment. Thus the rising and setting of the sun are phenomena. The bedded structure of sedimentary rocks is a phenomenon, &c.

Physics—[Gr. *physis*, nature.] The name of a branch of Science which treats of those properties and affections of bodies which do not depend on life. Chemical properties and phenomena are also now generally excluded from the domain of Physics. The properties of matter, such as weight, density, hardness, elasticity, &c., and the laws of heat, light, sound, electricity, &c., are comprehended under the general term Physics.

Planet—[Gr. *planetes*, wandering.] The earth and other celestial bodies, exclusive of the satellites and comets, that circulate round the sun.

Plateau—[Fr. a *plateau*, a tray, platform, tableland.] The flat or undulating surface of a tract of country, elevated a considerable height above the sea. Ex.: Malwa, Maisúr, Tibet, the Khási Hills.

Pole—In Geography, the two extremities of the earth's axis. [See that word.]

Race—Tide-race. See page 39.

Radiation—[Lat. *radio*, I shine or emit beams.] In Physics the form in which heat and light are emitted from a hot or luminous body to other bodies at a distance; in which, for example, the sun's heat and light pass through the interplanetary space, with a velocity of 180,000 miles in each second of time.

Rapid—The swift current of a stream or river where it flows down a steep slope.

Ravine—A narrow valley or channel cut by a stream with steep, but not absolutely precipitous sides.

Reef—A rocky surface, but little submerged beneath the sea, so that the water above it is too shallow to be navigable.

ROCHE MOUTONNEE—[Fr.] A term applied to rocky surfaces that have been rounded off and polished by the passage of a glacier.

ROCK—In Geology, applied to any kind of formation, whether hard and coherent or otherwise. Granite, sandstone, gravel, sand, and clay are equally classed as rocks.

SANDSTONE—A coherent rock, formed of grains of sand cemented together by some chemical deposit, usually silica or a compound of lime and carbonic acid.

SATURATION—[Lat. *saturatio*, a filling, satisfying.] In Chemistry, applied to that condition of a solution of some soluble substance, in which the maximum quantity is dissolved that the liquid is capable of holding permanently at its actual temperature. The same term was originally applied to the intermixture of water vapour with air by Leroi on the erroneous view that the vapour is held by the air in solution; in this application, the atmosphere is said to be saturated when it contains as much vapour as can exist in it at its actual temperature. The two cases are now known to depend on totally different conditions, but the term saturation is still in use to express the above fact, notwithstanding the acknowledged error of theoretical views that suggested its use.

SEDIMENT—[Lat. *sedeo*, I settle.] Any solid matter that settles down from a fluid. Hence

SEDIMENTARY ROCKS—are those formed of clay, mud, sand, &c., that has settled down from water as explained in Chapter IV.

SERIES—In Geology, a succession of stratified deposits formed without interruption; or, in certain cases, with interruptions, of minor importance to those which mark the beginning and end of the series.

SHALE—Stratified deposits, originally of clay or fine sand, hardened and compacted by pressure, and readily splitting up along the planes of deposition.

SHOAL—A shallow place in the sea or in any large body of water.

SILT—The very fine sediment, slowly deposited from most river waters when still and undisturbed.

SIMOOM—[Ar. *Samún.*] A name given to an intensely heated, stormy wind, that blows occasionally in the Arabian deserts. It is also sometimes felt in Sindh.

SNOW-LINE—See page 81.

SOLAR SYSTEM—The sun, together with all the planets, comets and other bodies that circulate around it, as the central body of the system.

SPECIES—There are few terms used in science, the meaning of which is less easy to define rigorously, or when defined to adhere to in practice, than that of this term. The definition of a species, generally given, is that it includes all animals related to each other by a common descent; or (since this can never be ascertained in fact) all those that resemble each other as closely as those known to have a common descent. Thus all the Tigers of Asia are regarded as one species, but the tiger and the leopard are different species. The horse and the domestic ass are different species, but all existing horses are of the same species. But there are great difficulties, practically, in fixing the limits of a species; and many naturalists at the present day are of opinion, that animals of very different species, perhaps all animals whatever, have a common descent. On this view a species consists of those individual animals or plants which resemble each other so closely, that it is convenient to call them by the same name; and this is the practical meaning of the term, whatever hypothesis may be held regarding the origin of species.

SPIT—A narrow strip of land running out into the sea, generally parallel with the coast line. See page 108.

SPRING TIDES. See page 37.

STEPPES—The great plains of Southern Russia; uncultivated wastes, destitute of forest.

STORM WAVE—The great sea wave which accompanies a cyclone. See page 149.

STRATUM, plural STRATA—[Lat. *stratum*, something spread out.] In Geology, the individual layers constituting sedimentary formations; whence these are also called stratified rocks. But the term may be applied to any mass of matter, regarded as consisting of horizontal layers. Thus we speak of the lower and upper strata of the atmosphere.

SUB-MARINE—[Lat. *sub*, under; *mare*, the sea.] Applied to any thing that is formed or exists beneath the sea.

SUB-SOIL—That which lies beneath the superficial layer of the soil.

SURF—The foam of breaking waves.

SWELL—Long rolling undulations of the sea surface, being waves propagated from some distant locality where a strong wind is blowing.

TABLELAND—A synonym for a plateau. See that term.

TALUS—See DEBRIS.

TEMPERATURE—[Lat. *temperatura*, from *tempero*, I divide, duly or proportionally.] Applied exclusively to express degrees of heat or cold, as measured by the thermometer or some similar instrument. The energy of the heat given out by a body.

THERMOMETER—[Gr. *therme*, heat; *metron*, a measure.] An instrument used for measuring temperature. See page 60. In the thermometer commonly in use in this country, known as Fahrenheit's thermometer, the temperature at which ice melts is called 32 degrees, and that at which water boils at the level of the sea, 212 degrees. The zero from which these degrees are counted and the magnitude of the degrees themselves, have been arbitrarily assumed. The zero is, in fact, obtained by immersing the instrument in melting ice, then in the steam from boiling water, and marking on its stem the height indicated in each case; the interval, as measured on the instrument, is divided into 180 parts and finally 32 of these parts are set off below the freezing point. The zero does not therefore express absolute cold or the entire absence of heat; a state of things never yet attained; but which would be attained at about 460 degrees below this zero.

TIDE—See page 34, *seq.*

TORNADO—[Span. *tornar*, to turn.] A name for a whirlwind; a small but violent storm in which the wind blows spirally around a central calm.

TRADE-WINDS—See page 27. Winds which, in the Atlantic and Pacific Oceans, blow on both sides of the equator, and in the Indian Ocean on the south of it, with but little change of direction or place throughout the year. Their direction south of the equator is from south-east; north of the equator from north-east; and where these two winds meet on, or near the equator, the air is calm, and heavy showers are very prevalent. The air brought by the Trade-winds ascends to a great height over this belt of calms, and then flows away to north-west and south-west in two upper currents termed the Anti-trades. The *Trade* winds are so called because they hold a certain *trade* or course, and not, as might be inferred, because they facilitate commerce.

TRAP—[Swedish *treppe*, a step.] See pages 49, 50.

TRIBUTARY—See **AFFLUENT**

TROPIC—[Gr. *trope*, turning, from *trepo*, I turn.] The tropics are two circles drawn round the earth parallel to the equator at a distance of nearly 23½° on each side of it. At all places situated on the northern tropic, called the tropic of Cancer, the sun is vertical at noon on the 21st June. At all places on the Southern tropic, or tropic of Capricorn, on the 21st December. At all places between the tropics, or in the Tropical zone, the sun is vertical on two days in each year. But at places beyond the tropics it is never vertical.

UPHEAVAL—A geological term for the process by which certain tracts of the earth's surface are raised to higher levels, relatively to those around them; by which, for instance, a sea bottom becomes dry land, or part of a plain is lifted up to form a mountain chain.

UPLANDS—High plains, or the gentler slopes of a hilly country.

VAPOUR—The gaseous or air-like form of substances which, at ordinary temperatures, are fluid or solid.

VEGETABLE MOULD—Earth containing a considerable proportion of decayed vegetable matters, such as is found in forests, swamps, &c.

VOLCANO—[Ital. *volcano*, from Lat. *Vulcanus*, the god of fire.] See pages 61, *seq.*

WADI—[Ar. *wádí*, a valley or low ground.] The ravines and valleys of Arabia, most of which are destitute of water.

WATERSHED—[*Water*, and Anglo-Saxon *sceadan*, to part or divide.] See page 90, where, however, the assigned derivation of the second syllable is erroneous.

Wave—This term is applied to any oscillating (backward and forward or up and down) motion, propagated through a mass of any substance, whether solid, liquid or gaseous. In a water wave, such as may be produced by throwing a stone into water, the motion of any particle of water to a certain limited depth is both up and down, and at the same time backwards and forwards; but it is not carried forward with the wave, which is simply the motion transmitted from one particle of water to another. In an earthquake, and in that motion of the air which causes sound, each particle of rock or air vibrates very rapidly backwards and forwards, each transmitting its motion to the next, and (if there be but a single wave) then coming to rest.

Weathering—A geological term expressing the chemical action of rest, the atmosphere, or more especially of the Carbonic acid, oxygen and water vapour, on the rocks of the surface, causing them to decompose.

Windward—The direction from which the wind blows: also applied to that face of a hill or mountain on which the wind blows.

Zoology—[Gr. *zoon*, an animal; *logos*, a discourse.] The branch of Natural History which treats of animals, more especially their classification, habits and distribution.

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